Using Animated Computer Simulation to Determine the Optimal

Resource Support for the Endodontic Specialty Practice at Fort Lewis

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ANIMATED COMPUTER SIMULATION WAS USED IN THIS STUDY TO DETERMINE THE OPTIMAL RESOURCE SUPPORT (DENTAL ASSISTANTS AND DENTAL TREATMENT ROOMS) FOR THE ENDODONTIC SPECIALTY PRACTICE AT FORT LEWIS, WASHINGTON. MEDMODEL HEALTHCARE SIMULATION SOFTWARE WAS USED TO COMPARE FIVE SCENARIOS OR MODELS WITH VARYING NUMBERS OF DENTAL ASSISTANTS AND DENTAL TREATMENT ROOMS. THE MODELS WERE RUN FOR 250 REPETITIONS TO SIMULATE ONE YEAR OF OPERATION. THEN THE MODEL OUTPUT DATA WERE ANALYZED WITH STATISTICAL TESTS, AND THE MODELS WERE COMPARED USING A DECISION MATRIX WHICH INCORPORATED THE DENTAL ACTIVITY COMMANDER'S PREFERENCES AND THE RELATIVE PERFORMANCE RATING OF EACH MODEL. ONE-WAY ANALYSIS OF VARIANCE TESTS INDICATED THAT THERE WERE SIGNIFICANT DIFFERENCES ($p < .0001$) BETWEEN THE FIVE COMPUTER MODELS. THE MODEL WITH TWO DENTAL ASSISTANTS AND THREE DENTAL TREATMENT ROOMS WAS DETERMINED TO HAVE THE BEST OVERALL PERFORMANCE, AND THEREFORE, TO POSSESS THE OPTIMAL RESOURCE SUPPORT. BASED ON THE RESULTS OF THIS STUDY, IT WAS RECOMMENDED THAT THE ENDODONTIST BE ASSIGNED TWO DENTAL ASSISTANTS AND BE GIVEN ACCESS TO THREE DENTAL TREATMENT ROOMS, IF POSSIBLE.

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Abstract

Animated computer simulation was used in this study to determine the optimal resource support (dental assistants and dental treatment rooms) for the endodontic specialty practice at Fort Lewis, Washington. MedModel® Healthcare Simulation software was used to compare five scenarios or models with varying numbers of dental assistants and dental treatment rooms. The models were run for 250 repetitions to simulate one year of operation. Then the model output data were analyzed with statistical tests, and the models were compared using a decision matrix which incorporated the Dental Activity Commander's preferences and the relative performance rating of each model. One-way Analysis of Variance tests indicated that there were significant differences ($p<.0001$) in the five computer models. The model with two dental assistants and three dental treatment rooms was determined to have the best overall performance, and therefore, to possess the optimal resource support. Based on the results of this study, it was recommended that the endodontist be assigned two dental assistants and be given access to three dental treatment rooms, if possible.

Table of Contents

Appendixes

List of Tables

List of Figures

Chapter 1

Introduction

Computer simulation is a widely used operations research tool which can be used to evaluate, improve, and optimize processes (Benneyan, 1997). It has been used in health care research for many years. However, advances in computer systems and software, along with a greater availability of personal computers has made computer simulation even more useful to health care analysts.

As the healthcare market becomes increasingly competitive, health care organizations (HCO) must become more efficient to remain viable. Computer simulation can be extremely useful in helping HCOs improve their processes and increase efficiency.

Conditions which prompted the study

Today the requirement to become more efficient extends well beyond the "for profit" HCOs and includes the Military Health System (MHS) as evidenced by the introduction of TRICARE, the Department of Defense's (DoD) managed care model. As part of the MHS, the U.S. Army Dental Care System (ADCS) has also been keenly aware of the need to achieve greater efficiency and productivity. However, the ADCS's attempt to face this challenge has been complicated by recruitment and retention difficulties, as well as by a requirement to meet a new DoD dental readiness goal for activity duty forces.

The ADCS has not been able to meet its accession goals since at least 1992, and the number of losses have been greater than the number of accessions, as depicted in Figure 1 (M. Carino, personal communication, March 20, 1998).

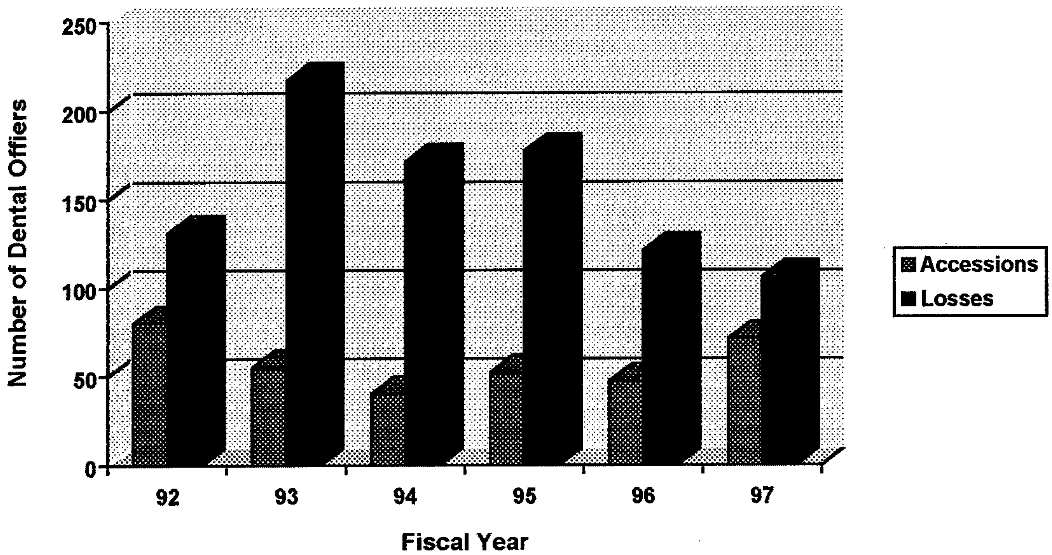


Figure 1. Yearly Accessions and Losses of Dental Corps Officers. [Source: Office of the Surgeon General, 1998.]

Some of the reasons the ADCS has had difficulties with recruitment and retention include: inadequate compensation combined with large student loan repayments and an improved economy with good civilian opportunities. A shortage of Dental Officers, particularly in the last five fiscal years (FY), has led to an increased dependence on contracting, usually at an increased costs (Appendix A, Table A1). In FY 96, there were 60 contract dentists in the Continental United States (CONUS) and 36 outside of the Continental United States (OCONUS). The numbers increased in FY 97 to 128 contract dentists in CONUS and 40 in OCONUS (L. Horning, personal communication, October 1, 1997).

Before January 1996, each branch of the military service set its own dental readiness standard or metric based on the Department of Defense Standardized Dental Classification System (HA POLICY 97-020). The DoD classification system includes four dental classifications (Appendix B) summarized below:

- Class 1 - no dental treatment needed.
- Class 2 - dental treatment needed; no risk of dental emergency within next 12 months.
- Class 3 - potential dental emergency within next 12 months.
- Class 4 - dental status unknown; no record and/or no panorex.

Personnel in dental class 1or 2 are considered to be deployable. Generally, personnel in dental class 3 or 4 are considered to be non-deployable without a waiver by a general officer.

Each of the three services (Army, Navy, and Air Force) had basically adopted a goal of having 90% of their active duty personnel in a dental class 1 or 2. However, in a January 1996 memorandum (Appendix C), the Assistant Secretary of Defense (Health Affairs) [ASD(HA)]gave the three Service Dental Chiefs a goal of having 95% of all active duty forces in dental class 1 or 2 (HA POLICY 96-024). Achieving the "95%" goal is a significant challenge for the ADCS since the 1994 Tri-Service Comprehensive Oral Health Survey determined that only 66.7% of Army recruits and 87.4% of active duty Army personnel (excluding recruits) were dental class 1 or 2 (King, Poindexter, & Leiendecker, 1996).

Recently, the ADCS has launched a new initiative called the Dental Care Reengineering Initiative (DCRI) in an attempt to become more productive and efficient.

While the ADCS has consistently delivered quality dental care to its eligible beneficiaries, many ADCS leaders believed the practice patterns of the ADCS had been inconsistent and inefficient. The DCRI is aimed at improving the business practices and clinical efficiencies of the ADCS. To accomplish this, the DCRI proposes utilizing treatment teams based on a dental health care team delivery model widely used in the private sector. By incorporating the "best practices" of the private sector, the ADCS hopes to improve performance outcomes (Lambert, Nasser, & Wineman, 1997).

Under the DCRI operational plan, general dentistry teams will be responsible for the dental care of an assigned panel of patients. Similar to the "teams" used in the private sector model, the general dentistry teams in the DCRI will consist of one dentist, multiple dental assistants, a hygienist, and a treatment coordinator. Each team will utilize three or four dental treatment rooms (DTRs) including the DTR utilized by the dental hygienist. The treatment coordinators will be responsible for scheduling appointments for the impaneled patients. Dental assistants on the teams will be expected to provide the maximum amount of services allowable under state law and consistent with their skill level. The DCRI also proposes using a central sterilization room instead of autoclaves in each treatment bay, when possible, to increase efficiency.

The DCRI evolved from the ADCS's "Concept and Feasibility Plan for the Implementation of a Team Dental Health Care Delivery Model" and was approved by the ADCS Board of Directors in February 1997. The DCRI concept was approved by The Surgeon General of the Army in March 1997 and by ASD (HA) in April 1997 (Lambert, Nasser, & Wineman, 1997).

The DCRI officially began on October 1, 1997 with DC#3 at Fort Bliss, Texas and Taylor DC at Fort Campbell acting as beta test sites. Perkins DC at Fort Hood, Texas was to become the third beta test site on November 1, 1997 (Nasser, 1997).

Prior to beta testing the DCRI plan, animated computer simulation was used to evaluate the dental treatment team concept proposed in the DCRI (Gebhart, Wong, & Grimes, 1997). Simulation was used to determine the optimum mix of dental assistants and DTRs per general dentist. The results of the computer simulation supported the mix of dental assistants, DTRs, and dentists proposed in the DCRI.

On June 9, 1997 the results of the computer simulation study previously mentioned were presented to the Dental Command (DENCOM) staff and to members of the team which developed the DCRI. Following a discussion of the results of computer simulation study of the general dentistry teams proposed in the DCRI, the group discussed the value of computer simulation in decision support and identified areas of interest for future studies. This group also concluded that a logical extension of the computer simulation study would be to determine the optimal assistant-to-dentist ratios for other dental specialties, such as prosthodontics, periodontics and endodontics.

Statement of the Problem or Question

U.S. Army Dental Care System (ADCS) has been keenly aware of the need to adopt better business practices and become more efficient. At the same time the ADCS has attempted to face this challenge, it has struggled with recruitment and retention difficulties, as well as with an increased readiness mission. Therefore, the ADCS has been challenged with meeting an expanded dental readiness mission with limited resources. To meet the challenge, the ADCS must adopt practices and allocate its

resources to achieve greater efficiency and productivity. One important way to maximize efficiency in dental clinics is to optimize the resources (dental assistants and DTRs) available to support providers. This research effort will focus on determining what are the appropriate resources (dental assistants and DTRs) to optimally support the endodontic specialty practice at Dental Clinic #2, a clinic representative of many of the dental clinics in the ADCS. Two basic questions to be addressed by this research effort utilizing animated computer simulation are:

1. What is the optimum number of dental assistants per endodontist at Dental Clinic #2, Fort Lewis, Washington?
2. What is the optimum number of dental treatment rooms per endodontist at Dental Clinic #2, Fort Lewis, Washington?

Literature Review

Dental productivity and efficiency studies. During the 1960's, the dental community became increasingly interested in improving dental practice productivity and began using time and motion studies to investigate dental operations. Concern over the potential shortage of dentists further supported the use of time motion studies to investigate productivity. Klein (1944) suggested that some of the potential benefits of using dental assistants was improved productivity and reduced work related stress. Subsequent studies have confirmed the positive effects, as suggested by Klein (1944), of dentists using four-handed dentistry techniques (a seated dentist assisted by a seated dental assistant) and dentists delegating duties to assistants (e.g. passing instruments, changing burs, arranging/adjusting dental equipment, preparing dental filling materials, making preliminary impressions, and placing rubber dams). The potential benefits of

using chairside dental assistants have also been shown in recent studies. In a 1996 survey of dental practices, general dentists who utilized chairside dental assistants spent an average of 3.3 minutes less on amalgam restorations and 5.4 minutes less on molar root canal therapy than did dentists who were not assisted by chairside dental assistants (ADA Survey Center, 1998).

Kilpatrick (1971) examined the effects of varying dental assistant-to-dentist ratios on productivity, and found one and two dental assistants per dentist will improve productivity by averages of 15% and 29%, respectively. However, the averages in Kilpatrick's (1971) study are considerably smaller than those found in studies by other investigators. Waterman (1952) and Arnold (1969) reported that using one dental assistant reduced a dentist's working time by about 50%, and Waterman (1952) reported as much as a 75% reduction in dentist working time when two dental assistants were used. In a study by Ganssle (1995) an assistant-to-dentist ratio greater than 1:1 was recommended. However, Boulier's (1974) study estimated an optimal assistant-to-dentist ratio of 1.5:1 (as cited in Lipscomb & Schefler, 1975). According to the American Dental Association, the percentage of dentists employing only one chairside dental assistant between 1990 and 1995 decreased, while the percentage of dentists employing two or more dental assistants increased (ADA Survey Center, 1998). In 1995, 43.2% of the dentists surveyed employed one chairside dental assistant and 49.7% of the dentists employed two or more dental assistants.

In studies of the use of multiple DTRs, Klein (1944) indicated that using multiple DTRs and/or dental assistants increase the "total patient-load capacity" without any appreciable decline in quality. Parker (1978) determined that dental officers using two

DTRs in U.S. Army Dental Clinics were more productive when they were supported by two dental assistants. In a similar study of 147 Army Dental Clinics, it was determined that the productivity of dentists was increased when the dentists utilized multiple DTRs (King, Brunner, & Mangelsdorff, 1982).

Computer simulation. Computer simulation imitates the operation of an actual process over a period of time, and it can be used to evaluate, improve and optimize a process (Benneyan, Horowitz, & Terceiro, 1994). Animated characters, such as patients, are utilized in animated computer simulation to make the simulation appear more realistic. Some advantages of using computer simulation include: (a) large complex systems can be emulated; (b) not limited to normal distributions, but can utilize any distributional phenomena; (c) may serve as a "what if" decision support system; (d) less expensive way to study a process; and (e) permits "time compression" so simulation data can be collected quickly compared to months or years that would be required by the actual process. Two major disadvantages are: (a) developing the simulation model can require a considerable amount of time and (b) running the simulation can require a considerable amount of computer time. However, these disadvantages are becoming less significant with the continual advancements in computer hardware and software (Benneyan, Horowitz, & Terceiro, 1994).

Decision support. Computer simulation is a cost-effective way for decision makers to test alternatives and make more informed decisions. In fact, computer simulation is most often used as a "decision support tool." By comparing processes, staff, and resources over a range of "what if" questions, computer simulation can lead to "optimal" decisions (Benneyan, Horowitz, & Terceiro, 1994). Ditch & Hendershott

(1997) demonstrated that simulation modeling is particularly well suited to supporting decision making where the work processes are similar and the objectives are dynamic. Schroyer (1997) used simulation as a decision support tool when trying to decide if the teaching mission of Baystate Health Systems should be abandoned or significantly curtailed in order to be more efficient after they moved into their new facility.

Steps in computer simulation. MCGuire (1997) outlines ten steps necessary to complete a project using computer simulation. The steps include the following:

1. Identify the process.
2. Define the goals.
3. Formulate the model.
4. Collect data.
5. Build the model.
6. Verify the model.
7. Validate the model.
8. Set up alternative models for evaluation.
9. Run the alternative models and evaluate the results.
10. Choose the best alternative or combination of alternatives.

Although more time consuming than using a Delphi method, Keller, Harrell, & Leavy (1991) and Cirillo & Wise (1996) recommend collecting empirical data and using distribution fitting software, such as Stat::Fit®, to build empirical distributions. According to these authors, models that use distributions built from empirical data are more accurate than models that use theoretical distributions or "best guess" data.

Distribution fitting software builds empirical distributions that best fit the collected data, thereby enabling the model to more closely mimic the actual process being studied (Lowery, 1996). However, the distribution that best fits the empirical data may not necessarily be the normal distribution. For example, a distribution fitting software might indicate that the empirical provider service times best fit a Lognormal, Weibull, or Beta shaped distribution. McGuire (1997) stated the results of simulation are far more accurate when fitted distributions are used than just assuming the distribution is normal.

Verification is making sure the model runs as expected by the analyst, and includes debugging. Validation is making sure the model runs as expected by the client (Dawson, Ulgen, O'Connor, & Sanchez, 1994). Once the basic model has been verified and validated, it can be altered based on "what if" scenarios to create alternative models which can be tested and compared to the original model .

Medical or health care simulation models. Health care simulation software has been used in numerous ways to study and improve health care delivery systems. Some common applications of computer simulation in health care include studying staffing ratios, clinic operations and designs, and patient waiting times.

Wilt & Goddin (1989) used simulation to determine the staffing requirements of a new outpatient diagnostic center in the Osteopathic Medical Center of Philadelphia. The medical center developed a new clinic floor plan and tested both the equipment (X-ray, CAT scan and mammography equipment, etc.) locations and staffing (clerical staff, technicians, phlebotomists, radiologists, and physician) combinations in order to determine which provided the most timely (reduced waiting times) care to the patients.

The results of the study produced the optimal staffing ratios and recommended changes to the floor plan of the facility.

Using computer simulation, Dawson, Ulgen, O'Conner, & Sanchez (1994) conducted a staffing level study for St. Joseph Hospital and Medical Center, a 607 bed acute care facility located in Detroit, Michigan. The purpose of simulation was to determine the best nurse and technician staffing level for the emergency center. After developing flow charts and using a triangular distribution for patient arrivals, the evaluation team used simulation to evaluate various nurse and technician staffing combinations. Using the results of the simulation as an aid, the evaluation team was successful in persuading the hospital's chief executive officer (CEO) to accept their recommendation staffing three groups (triage nurses, emergency room nurses, and emergency room technicians) with additional full time equivalents (FTE).

Ledlow (1996) utilized animated simulation to determine the optimal provider staffing and process configuration for an Army family practice clinic in Heidelberg, Germany. His study determined that an alternative model with eight physicians was significantly better than the status quo model with five physicians or the other alternative model consisting of a combination of physicians and physician extenders.

Allen, Ballash, & Kimball (1997) used computer modeling and simulation to determine the optimal number of support staff and exam rooms for primary care physicians in a family practice clinic. After determining four potential scenarios involving different ratios of providers and support staff, they simulated each scenario and determined the most efficient staffing mix.

Simulation was also used to determine the appropriate staffing ratio of an emergency room (Kirtland, Lockwood, Poisker, Stamp, & Wolfe, 1995). The goals of the simulation were to improve the operation of the emergency room and reduce patient throughput times by properly determining appropriate staffing levels. The evaluation team used simulation to examine eleven different staffing ratio alternatives and to determine the most efficient staffing ratio. After completing the simulation, the evaluation team stated that using simulation as an analysis tool proved to be an effective method to test and evaluate alternatives before implementing changes.

Some proponents of using simulation to determine staffing ratios believe that simulation is superior to traditional staffing analysis techniques because it takes into account the dynamic nature of what is being studied (Dawson et al., 1994). Another advantage is simulation allows the facility to create and evaluate various staffing ratio scenarios without a great investment in time or money.

Simulation has been used to evaluate changes in staffing, patient flow and/or clinic design to improve patient waiting time. Edwards et al. (1994) used computer simulation to study waiting times in two medical clinics. Using different clinic structures, the simulation determined patient waiting times. The study showed that waiting times could be reduced 30% by changing the existing process.

Hendershott (1995) used computer simulation to evaluate the operation of a GI laboratory. The most appropriate process flow, staffing, and equipment level were determined with the help of simulation.

Kalton, Singh, August, Parin, & Othman (1997) used computer simulation to improve the efficiency of the University of Michigan Breast Care Clinic, a multi-

disciplinary clinic with oncologists, radiologists, plastic surgeons, and psychiatrists. Patients complained about long waits and delays in getting follow on appointments. The simulation model evaluated a new scheduling procedure, analyzed the effects of changing patient loads, and determined an efficient mix of patients.

Benneyann (1997) examined some of the factors that impact on patient waiting times in a pediatric clinic. He evaluated a number of "what if" ideas with computer simulation. His study determined the optimal number of additional support staff, additional exam rooms, and additional pediatricians required to achieve the greatest reduction in patient waiting time.

Dental simulation models. While there are numerous examples in the literature of medical computer simulation models, there is a noticeable lack of published studies involving dental simulation models. Although not an animated simulation model, Kilpatrick, MacKenzie, & Kisko (1976) presented a model for a dental practice analysis using computer simulation. This appears to be the only dental computer simulation model to be published at this point in time. However, at least two unpublished dental studies involving Army dental clinics have been conducted. Clouse, Schmidt, & Sarthou (1997) used animated computer simulation to evaluate the use of central sterilization in Army dental clinics. Their study indicated that using a central sterilization system is more efficient than using individual sterilizers in each of the clinic treatment areas. As discussed earlier, computer simulation was also used to evaluate the general dentistry team concept proposed by the DCRI (Gebhart, Wong, & Grimes, 1997).

Purpose

The purpose of this research effort is to utilize animated computer simulation to determine the optimum resources (dental assistants and DTRs) required to support the endodontic specialty practice at U.S. Army Dental Clinic #2 (DC#2), Fort Lewis, Washington. An additional objective of this study is to provide the ADCS a "re-usable" computer simulation model that can be adapted to serve as a decision support tool at other Army dental clinics.

Supporting objectives. The primary objective is supported by the following enabling or supporting objectives:

- Develop a simulation model which represents the status quo of the endodontic specialty practice at DC #2.
- Determine the current ratio of dental assistants and DTRs per endodontist at DC #2.
- On a floor plan of DC #2, determine the current location of the entrance/exit, the waiting room, the reception desk, the x-ray room, the autoclave(s), and the DTRs utilized by the endodontist.
- Determine the patient flow and associated times for endodontic patients at DC #2. The times include patient arrival times, provider service time (exam/eval times and treatment times), x-ray times, and DTR clean-up/set-up times.
- Determine the current daily number of patients seen at DC #2 for endodontic care.

Variables. Seven different independent and dependent variables will be included in this study. The specific variables are:

1. Dental assistants (independent variable).

2. DTRs (independent variable).

3. TIME (dependent variable), the total time a patient spends in the clinic.

4. TOTALPT (dependent variable), the total number of endodontic patients seen daily.

5. PROVUTIL (dependent variable), provider utilization.

6. ASSTUTIL (dependent variable), dental assistant utilization.

7. DTRUTIL (dependent variable), DTR utilization.

Hypotheses. A total of five models will be simulated. The initial model represents the status quo for the endodontic specialty practice at DC #2 and will be named the Status Quo Model. There will be four alternative models which reflect specific changes in the number of dental assistants and/or the DTRs utilized by the provider. The alternative models will be named the Alternative Model # (1, 2, 3, or 4).

Eleven hypotheses will be tested in this study (see Appendix D). The first hypothesis that will be tested is related to model validation. It states there is no significant difference between the empirical data and the Status Quo Model. The remaining hypotheses involve comparisons between the models, and state there are not significant differences between any of the models (Status Quo Model and Alternative Models).

Chapter 2

Method and Procedures

Animated computer simulation models were developed to represent the endodontic specialty practice at the U.S. Army Dental Clinic #2, Fort Lewis, Washington. The institutional version of MedModel® 3.5 Healthcare Simulation software was used to develop and evaluate the models. The institutional version of MedModel® does not have constraints on the number of locations, resource types, entity types, and attributes that can be used.

Computer simulation, a decision support system, was used to help determine the optimum number of dental assistants and DTRs required to support the endodontic specialty practice at DC#2. Dental Clinic #2 was modeled because: (a) its design is representative of the modern dental clinic design commonly used by the ADCS; (b) currently the only endodontist at Fort Lewis practices at DC #2.

Definitions

To help provide clarity, the following definitions are provided:

- Endodontics - "that branch of dentistry concerned with the etiology, prevention, diagnosis, and treatment of diseases and injuries that affect the dental pulp, tooth root, and periapical tissue" (Jablonski, 1982).
- Endodontic therapy - a root canal treatment.
- Endodontist - "a dentist who specializes in or limits his practice to endodontics" (Jablonski, 1982).

- Provider service time - time the provider spends in the DTR with the patient. For the purpose of this study, provider service time includes the time the endodontist spends performing examinations or evaluations (exam/eval time) and endodontic therapy or surgery (treatment time).
- Support resources - for the purpose of this study, support resources include dental assistants and DTRs.

Description of the Modeled Clinic

Dental Clinic #2 is a modern, 27-chair clinic with open treatment bays. The support staff of DC#2 consists of 31 personnel who perform various clinical and administrative tasks (Appendix A, Table A2). The provider staff of DC #2 consists of 27 personnel and includes one endodontist, seven general dentists, one Oral & Maxillofacial Surgeon, one periodontist, one prosthodontist, ten dental residents, two dental therapy assistants (DTA), one Registered Dental Hygienist (RDH), and three military hygienists (91EX2).

An important difference between DC #2 and most other Army dental clinics is its secondary mission to support a general dentistry residency. Supporting the dental residency greatly limits the number of DTRs which are available to the provider staff. Approximately seven DTRs are utilized by dental residents who are completing rotations at DC #2.

The patient population of DC #2 is approximately 5,300 eligible beneficiaries. Patients can receive care at DC #2 by scheduling an appointment, or if necessary patients can present without an appointment for "sickcall" between the hours of 0700 - 0830 and

1230 - 1330. Dental Clinic #2 is opened for patient care Monday through Friday between the hours of 0700 - 1530. The clinic staff conducts meetings and/or physical training between 1530 - 1630 hours, Monday through Friday. Generally, two of the staff dentists are not available for patient care on Thursday mornings because they are providing lectures to the ten dental residents.

Currently, the endodontist at DC #2 usually utilizes two DTRs and two dental assistants. One of the DTRs is a lead-lined room with x-ray capability (room C-3 on the floor plan in Appendix E). The second DTR (room C-5 on the floor plan) does not have x-ray capability since it is in an open bay where it would be impractical to provide lead-lining. Typically, multiple radiographs are taken during endodontic therapy, therefore endodontists prefer DTRs with x-ray capability because they are more efficient.

Patients requiring difficult and/or time intensive endodontic therapy or surgery are usually referred to an endodontist. The endodontist has an important dental readiness mission since active duty personnel requiring endodontic therapy or surgery are considered Class 3 patients (non-deployable).

The normal flow of endodontic patients through DC #2 is depicted in Figure 2. Patients present to the clinic prior to their scheduled appointment time and sign in at the reception desk. After signing in, patients move to the waiting room where they wait for a dental assistant who will escort them to the DTR. At the conclusion of the appointment, patients receives a follow-up appointment, if necessary, and depart. The DTR is then prepared for the next patient by the dental assistant.

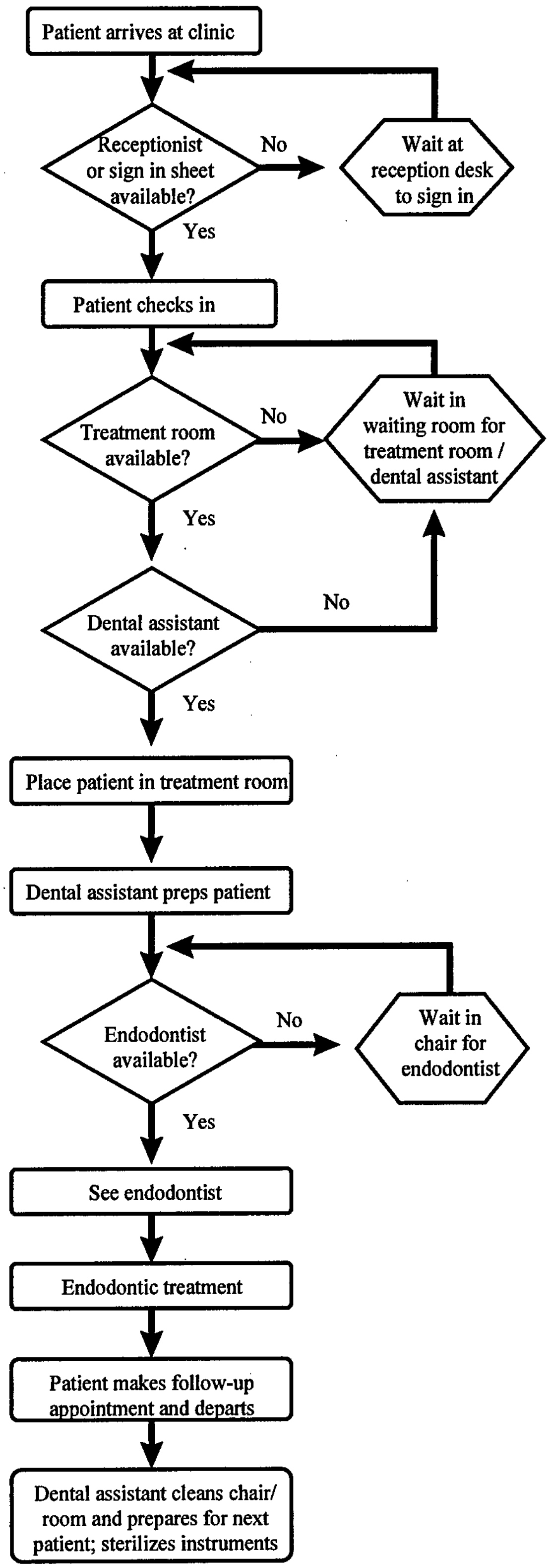


Figure 2. Endodontic Patient Flow Through DC #2.

<u>Model creation</u>

A Status Quo Model and four Alternative Models were created. The Status Quo Model was created first. It was important for the Status Quo Model to closely resemble the dental clinic and the endodontic practice being modeled since the Status Quo Model was the base model from which the Alternative Models were derived. The initial step in creating the model was to construct a floor plan for the simulated dental clinic from the floor plan of DC #2. Then a path network and various locations, such as the DTRs and the waiting room, were superimposed on the simulation floor plan. The path network established paths the animated characters would follow during simulations. Animated patients and clinic staff move along the path network and stop at various clinic locations, such as the waiting room or DTRs, for different length of times representing actual waiting times or provider service times.

All models included multiple locations, resources, and entities. However, statistics were only collected on the locations (waiting room & DTRs), resources (endodontist & endodontic assistants), and entities (exam/eval patients and treatment patients) actually involved in endodontic care at DC #2. Additional resource types (other dental assistants and providers) and entity types (other dental patients) were included in the models to simulate a fully staffed clinic and the typical daily patient volume and traffic at DC #2 (Appendix F). Since the additional resource and entity types were held constant in the Status Quo and Alternative Models, they would not account for any differences between the models.

Considerable effort was made to reproduce in the Status Quo Model the actual patient flow observed in DC #2 and depicted in Figure 2. The arrival times of animated

scheduled patients were based on actual patient appointment data. In the simulation, animated patients check in at the reception desk, then move to the waiting room. As soon as a dental treatment room and an animated dental assistant become available, the animated patient is escorted to the DTR by the animated dental assistant. Then the animated dental assistant prepares the animated patient for treatment. When the animated endodontist becomes available, the animated endodontist moves to the DTR and provides care for a predetermined length of time. The two different types of animated patients (exam/eval & treatment) are treated for different lengths of time. The provider service times were determined by a distribution based on empirical data collected at DC #2. At the end of the treatment time, the animated patient is given a follow up appointment, if necessary. The animated dental assistant then cleans the DTR, prepares the DTR for the next patient, and sterilizes instruments as needed.

Although the clinic normally operates from 7:00 a.m. to 3:30 p.m., the clinic entrance in the simulation model was closed 30 minutes early. This reduced the number of animated patients who arrived at the clinic too late to be treated before the end of the simulation cycle. Two 10-minute breaks and a 30-minute lunch break were incorporated in the model as scheduled down time for the animated dental assistants. A 30-minute lunch break was incorporated as scheduled down time for the animated endodontist.

The Status Quo Model was adapted to four different scenarios to create four Alternative Models. The only differences between the Status Quo Model and the Alternative Models was the number of dental assistants and/or DTRs. Table 1 illustrates the differences between the four Alternative Models and the Status Quo Model.

Table 1

Status Quo and Alternative Models

Model	Endodontist	Dental Assistants	DTRs
Status Quo Model	1	2	2
Alternative Model #1	1	1	1
Alternative Model #2	1	1	2
Alternative Model #3	1	2	3
Alternative Model #4	1	3	3

Data collection

Empirical data was used instead of using the Delphi or the "best guess" methods since it results in a more accurate model (Cirillo & Wise, 1996). The same investigator explained the data requirements and modeling process to members of the dental clinic staff who observed and recorded patient arrival times, provider service times, DTR preparation and sterilization time, and x-ray times. Data was recorded on sign in sheets and standardized data collection forms (Appendix G). Since the sign in sheets contained patient names and Social Security numbers, patient confidentiality was a concern. Patient confidentiality was maintained by restricting access to the sign in sheets and masking the patient names and Social Security numbers. After the data was collected, it was processed through Stat::Fit®, a curve-fitting software program within MedModel® 3.5. Based on a "Goodness-of-fit" Chi^2 test, Stat::Fit®, rank ordered all of the possible analytical distributions based on how they "fit" the observed data. For example, Stat::Fit® indicated that the Weibull distribution best fit the empirical provider service times for exam/eval patients. Figure 3 illustrates the fit of the Weibull distribution to the empirical data.

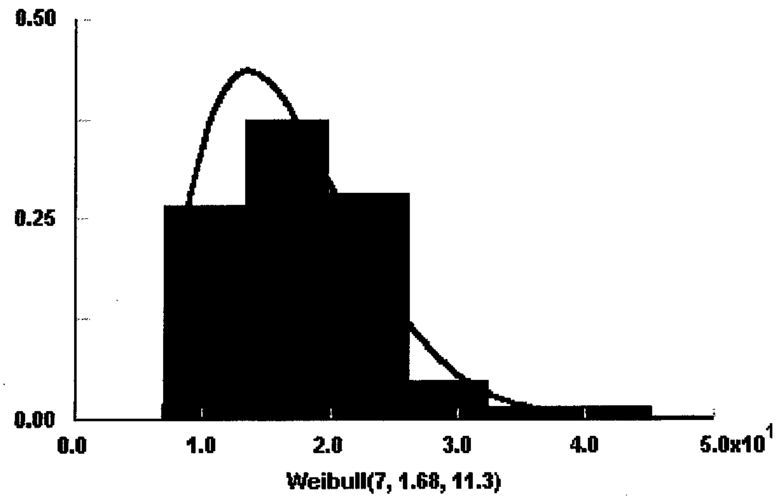


Figure 3. Fit of a Weibull shaped distribution to the empirical provider service times for exam/eval patients.

The distributions which best fit the observed data were selected and utilized in the processing logic of the computer model (see Appendix H). The model was run for 250 cycles to reproduce an average year's worth of operation (Hashimoto & Bell, 1996). Each cycle represents a typical clinic day.

Model Verification and Debugging

Model verification insures the model runs as the investigator expects it to run. Verification was facilitated by building the Status Quo Model in sequential steps. For example, the floor plan was added, then the path network and so on until the model was completed. The MedModel® Debugger and Trace options were used to test and follow the processing logic. These features of the MedModel® software allow the processing logic to be examined one statement at a time (PROMODEL Corporation, 1996). As a final step in model verification, the investigator took the Status Quo Model to a MedModel® course in December 1997 where a consultant from the PROMODEL Corporation reviewed the model and helped to "fine tune" it.

Model Validation

Model validation insures that the simulation model accurately mimics the actual endodontic practice at DC #2. Using a distribution fitting software, Stat::Fit®, to select distributions which best fit the empirical data helped insure a computer model was built that closely resembled the actual clinical practice. Credibility and face validity were established by demonstrating the Status Quo Model to the endodontist and the dental clinic staff. The Status Quo Model was also validated by using the independent sample t-test to compare the means of the model output data to clinic data (empirical data). Three different time variables (WAITTIME = patient waiting time; PROVTIME = provider in use time; and DTRTIME = DTR in use time) were compared to determine if significant differences exist between the times in the clinic and model data. The times in the clinic data were derived from the empirical data collected at DC #2, and the model data was generated by running 50 repetitions of the Status Quo Model in MedModel®.

Reliability

Another important criteria to satisfy was reliability which contributes to validity. Reliability insures the model has consistency and is "free of random or unstable error" (Cooper & Emory, 1995). The following steps were taken to establish reliability:

1. Standardized data collection forms were used (Appendix G).
2. The same individual trained all of the data collectors.
3. A second investigator randomly checked the accuracy of transferring the data to the software programs (Stat::Fit® and SPSS®). This investigator found that 100% of the 454 data points randomly sampled had been accurately transferred.

After the Status Quo Model was verified and validated, the number of patient arrivals was increased so that more simulated endodontic patients arrived at the clinic in the Status Quo and Alternative Models than could be treated. This allows the actual capacity, i.e. the total number of patients that can be seen, in each model to be compared.

Assumptions

This study employed the following assumptions:

- The data collected by the staff of DC #2 accurately represent typical work days.
- All dental assistants work at the same rate.
- All endodontists work at the same rate in all DTRs.
- The endodontic specialty practice at DC#2 represents the endodontic specialty practices in other dental clinics of the ADCS.
- There will be at least two DTRs with x-ray capability available to the endodontist.
- There is an infinite number of DTRs available to the endodontist.
- There is an infinite number of endodontic patients available for treatment at DC#2.
- Two hundred fifty cycles or repetitions represents one year's worth of operation (Hashimoto & Bell, 1996).

Statistical Test

The independent samples t-test in SPSS For Windows® was used to compare clinic data (empirical data) to data generated by running 50 repetitions of the Status Quo Model in MedModel®. The t-test tested the validity of the Status Quo Model, i.e. the ability of the Status Quo Model to mimic the actual endodontic specialty practice at DC #2, and hypothesis #1 (Appendix D). If no significant differences ($p>.05$) exist between

the clinic data and the model data, then the model is valid and the null hypothesis must be accepted.

After the Status Quo Model was validated and each computer model was run for 250 repetitions, the data was analyzed using SPSS For Windows®. Descriptive statistics of the results of the simulations were produced by the statistical software. Then the one-way Analysis of Variance (ANOVA), an inferential statistical test, was used to determine if statistical differences exist between the five simulation models. If the results of the ANOVA were significant ($p \leq .05$), a multiple comparison post hoc test, the Scheffe, was used to isolate the significant differences.

Decision Matrix

A decision matrix (evaluation matrix) was used to help determine which model performed best overall, and therefore possessed the optimal resources (Athey, 1982). The dependent variables served as the criteria in the decision matrix and the five computer models constituted the feasible alternatives or courses of action. The variables were weighted in the decision matrix based on the relative importance of each variable to the Commander of the Dental Activity at Fort Lewis. The "preference chart" method described by Athey (1982) was used to obtain the Commander's input on the relative importance of each variable and to assign each variable a weight (see Appendix I).

In the decision matrix, the models were assigned relative ratings ranging from "5" for the best result to "1" for the worst result. When the differences between two models were not significant, the relative ratings were averaged and both models were assigned the same number. For example, instead assigning a relative rating of "5" to the model

with the best result and a relative rating of "4" to the model with the second best result, they both were assigned a relative rating of "4.5" if the difference between the models was not significant.

Chapter 3

Results

After validating the base or Status Quo Model, five computer simulation models, each representing a different scenario, were run for 250 repetitions. Five dependent variables were studied and differences found between the computer models were tested for significance.

Model Validation

Table 2 displays the results of the independent samples t-tests used to test Hypothesis #1 and to validate the Status Quo Model. The actual times observed in the dental clinic (the empirical data) and the times generated in the Status Quo Model were not significantly different. For example, the mean waiting time in the clinic of 14.94 minutes was not significantly different (t=.206, p=.837) than the mean waiting time of 15.21 minutes generated in the model.

Table 2

Comparison of Clinic Data (empirical data) with Model Output Data

	Clinic Data	Model Data	t	Significance (α=0.05)
PROVTIME (minutes)	$\bar{x} = 38.83$ $\sigma = 31.34$ $n = 104$	$\bar{x} = 34.68$ $\sigma = 3.51$ $n = 50$	-1.331	.186
DTRTIME (minutes)	$\bar{x} = 44.36$ $\sigma = 35.21$ $n = 104$	$\bar{x} = 50.27$ $\sigma = 8.10$ $n = 100$	1.667	.098
WAITTIME (minutes)	$\bar{x} = 14.94$ $\sigma = 11.06$ $n = 104$	$\bar{x} = 15.21$ $\sigma = 4.88$ $n = 50$	.206	.837

Note. Equal variances not assumed.

Model Comparison

The Status Quo Model and the four Alternative Models were compared by examining the differences in the five dependent variables. Table 3 displays the descriptive statistics on the dependent variables in each of the computer models.

Table 3

Descriptive Statistics

	Status Quo (n = 250)	Alternative Model #1 (n = 250)	Alternative Model #2 (n = 250)	Alternative Model #3 (n = 250)	Alternative Model #4 (n = 250)
TIME (minutes)	$\bar{x} = 122.67$ $\sigma = 29.37$	$\bar{x} = 151.02$ $\sigma = 32.64$	$\bar{x} = 133.14$ $\sigma = 25.89$	$\bar{x} = 114.43$ $\sigma = 24.39$	$\bar{x} = 112.21$ $\sigma = 23.21$
ASSTUTIL (%)	$\bar{x} = 56.58$ $\sigma = 2.11$	$\bar{x} = 95.78$ $\sigma = 3.04$	$\bar{x} = 96.73$ $\sigma = 2.02$	$\bar{x} = 58.93$ $\sigma = 2.08$	$\bar{x} = 40.94$ $\sigma = 1.50$
PROVUTIL (%)	$\bar{x} = 85.46$ $\sigma = 4.13$	$\bar{x} = 74.26$ $\sigma = 2.78$	$\bar{x} = 77.06$ $\sigma = 2.89$	$\bar{x} = 89.48$ $\sigma = 4.00$	$\bar{x} = 91.43$ $\sigma = 4.20$
DTRUTIL (%)	$\bar{x} = 85.74$ $\sigma = 5.61$	$\bar{x} = 95.28$ $\sigma = 1.72$	$\bar{x} = 84.85$ $\sigma = 4.50$	$\bar{x} = 80.24$ $\sigma = 7.73$	$\bar{x} = 73.48$ $\sigma = 8.90$
TOTALPT	$\bar{x} = 10.32$ $\sigma = 1.30$	$\bar{x} = 8.65$ $\sigma = 1.06$	$\bar{x} = 9.13$ $\sigma = 0.83$	$\bar{x} = 10.59$ $\sigma = 1.30$	$\bar{x} = 10.73$ $\sigma = 1.21$

Time in Clinic. The dependent variable, TIME, reflects the total mean time the animated endodontic patients spent in the dental clinic in each of the computer simulation models. The variable, TIME, includes the time waiting in the waiting room and the time in the DTR. The mean time ranged from 106.68 minutes in Alternative Model #4 to 151.02 minutes in Alternative Model #1 (Table 3). Figure 4 illustrates the differences in

variable in the five computer models.

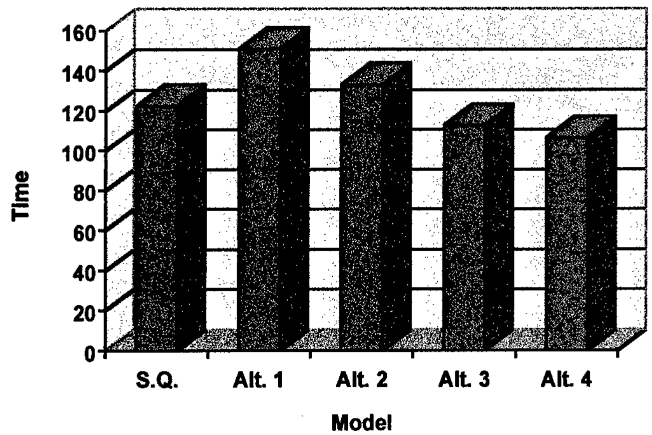


Figure 4. The mean time spent in the dental clinic by the animated patients.

The results of the one-way analysis of variance (ANOVA) of the dependent variable, TIME, are displayed in Table 4. The ANOVA revealed a significant difference between the five models (F=84.57, p<.0001). However, the multiple comparison post hoc test (Scheffe) in Appendix A, Table A3 indicated that the differences in the variable, TIME, in Alternative Model #4 (106.68 minutes) and Alternative Model #3 (112.88 minutes) were not significant (p=.936).

Table 4

One-way ANOVA of Dependent Variable: TIME

		Sum of Squares	df	Mean Square	F	Sig.
TIME	Between Groups	252441.20	4	63110.30	84.57	.0001
	Within Groups	929069.40	1245	746.24		
	Total	1181511	1249			

Note. Computed using alpha = .05; R^2 = .214.

Assistant Utilization. The highest utilization (96.73%) of the dental assistant occurred in Alternative Models #2 which has only one dental assistant (see Tables 1 and 3), while the lowest utilization (40.96%) occurred in Alternative Model #4 which has three dental assistants. Figure 5 illustrates the differences in the dependent variable, ASSTUTIL, in the computer models.

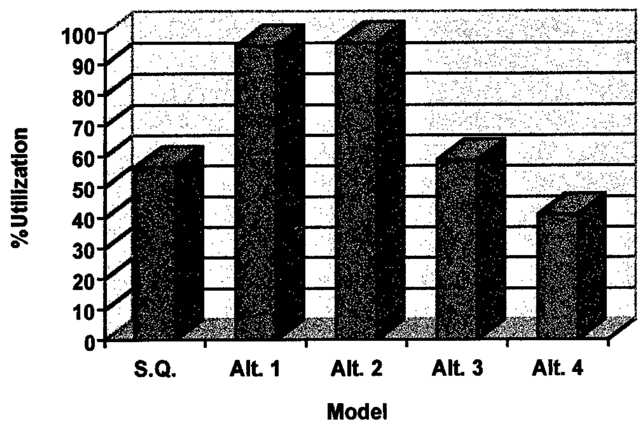


Figure 5. Percent utilization of dental assistants in each computer model.

The utilization of the dental assistant in Alternative Model # 1 (95.78%) was similar to the utilization in Alternative Model #2 (96.73%). The utilization of dental assistants was also similar in the Status Quo Model and Alternative Model #3 (56.58% and 58.80%, respectively). However, the differences in the utilization of dental assistants were found to be significant ($F=32421.95$, $p<.0001$) when all of the models were compared in an ANOVA (Table 5).

Table 5

One-way ANOVA of Dependent Variable: ASSTUTIL

		Sum of Squares	df	Mean Square	F	Sig.
ASSTUTIL	Between Groups	631578.50	4	157894.60	32421.95	.0001
	Within Groups	60063.14	1245	4.87		
	Total	637641.70	1249			

Note. Computed using alpha = .05; R^2 = .990.

Provider Utilization. The highest value for the dependent variable, PROVUTIL, occurred in Alternative Model #4 with 90.71% utilization, and the lowest value for PROVUTIL was 74.25% in Alternative Model #1 (see Table 3). The differences in the utilization of the provider (endodontist) in the five computer models is illustrated in Figure 6.

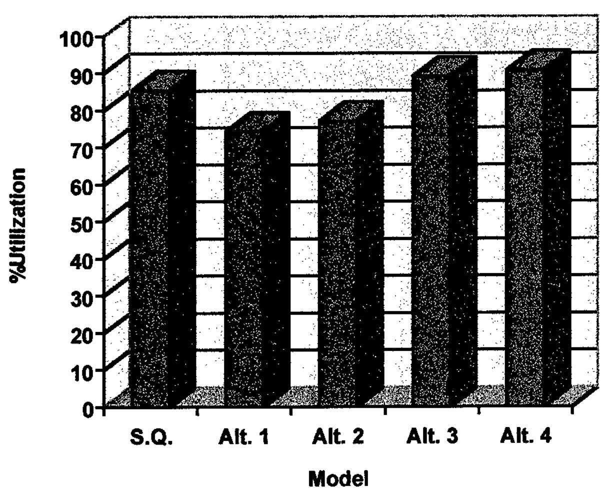


Figure 6. Percent provider utilization in each computer model.

The one-way ANOVA was used to test for significant differences in the dependent variable, PROVUTIL, in the five computer models. The differences were significant (F=1072.31, p<.0001) based on the results of the ANOVA which are displayed in Table 6.

Table 6

One-way ANOVA of Dependent Variable: PROVUTIL

		Sum of Squares	df	Mean Square	F	Sig.
PROVUTIL	Between Groups	57308.29	4	14327.07	1072.31	.0001
	Within Groups	16634.37	1245	13.36		
	Total	73942.66	1249			

Note. Computed using alpha = .05; $R^2 = .775$.

DTR Utilization. Utilization of the DTRs was higher in models with few DTRs. Figure 7 illustrates the difference in the percent utilization of the dental treatment room (DTR) in each of the computer simulation models. Alternative Model #1 with one DTR had the highest mean percent utilization of DTRs (95.28%), while Alternative Models #3 and #4, each with three DTRs, had the lowest mean percent utilization of the DTRs (79.89% and 71.60%, respectively).

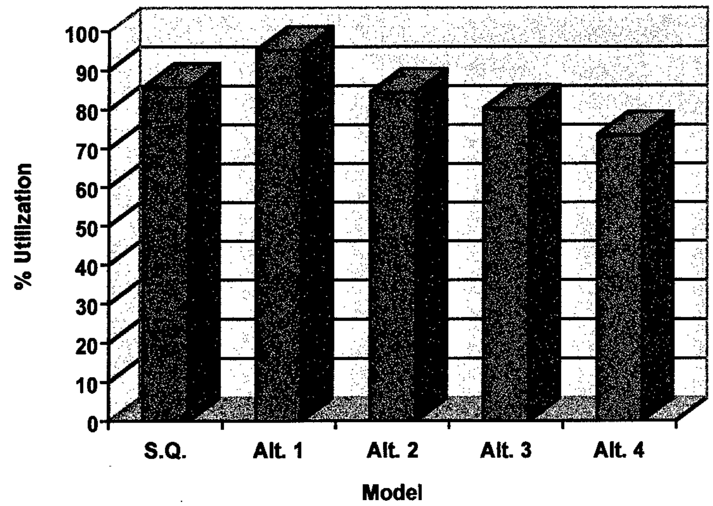


Figure 7. Percent utilization of the DTRs in each computer model.

The results of an ANOVA indicate there were significant differences (F=412.83, p<.0001) in means of the dependent variable, DTRUTIL, in the five computer models (Table 7). However, the post hoc multiple comparison test (Scheffe) in Appendix A, Table A6 revealed that the differences between the Status Quo Model and Alternative Model #2, were not significant (p=.641).

Table 7

One-way ANOVA of Dependent Variable: DTRUTIL

		Sum of Squares	df	Mean Square	F	Sig.
DTRUTIL	Between Groups	63931.96	4	15982.99	412.83	.0001
	Within Groups	48201.02	1245	38.72		
	Total	112133	1249			

Note. Computed using alpha = .05; R^2 = .570.

Total patients. More patients were seen in the computer simulation models which contained more DTRs and dental assistants. Alternative Model #1, the model with the smallest number of DTRs and dental assistants had a mean of 8.65 total patients, while Alternative Model #4 which had the most DTRs and dental assistants had a mean of 11.08 total endodontic patients. Figure 8 shows the total number of patients seen in each computer simulation model.

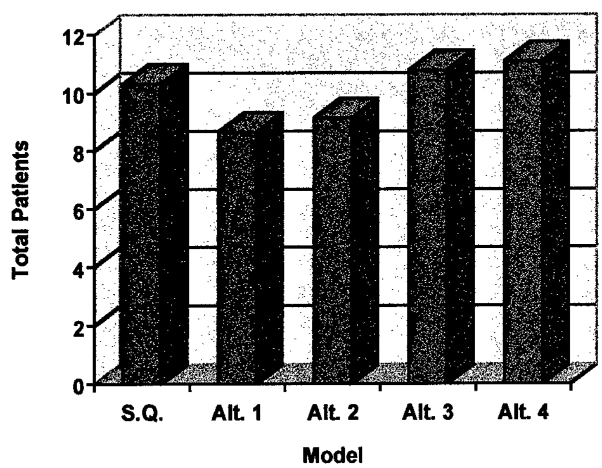


Figure 8. Total number of endodontic patients seen in each computer model.

An ANOVA found significant differences (F=164.59, p<.0001) between the means of the dependent variable, TOTALPT, in all of the models (Table 8). However, the results of the Scheffe test in Appendix A, Table A7 indicated that the significant differences did occur between the Status Quo Model and Alternative Model #3 (p=.138) or between Alternative Models #3 and #4 (p=.744).

Table 8

One-way ANOVA of Dependent Variable: TOTALPT

		Sum of Squares	df	Mean Square	F	Sig.
TOTALPT	Between Groups	872.68	4	218.17	164.59	.0001
	Within Groups	1650.27	1245	1.33		
	Total	2522.95	1249			

Note. Computed using alpha = .05; R^2 = .346.

Hypothesis Testing

Each of the hypotheses was tested by either the independent samples t-test or by the ANOVA followed by the Scheffe if the results of the ANOVA were significant. The first hypothesis which is related to the validity of the Status Quo Model was tested by the independent samples t-test.

Hypothesis #1.

H_0 #1: There is not a significant difference between the output data of the Status Quo Model and the empirical clinical data.

H_1 #1: There is a significant difference between the output data of the Status Quo Model and the empirical clinical data.

The results of three independent t-tests displayed in Table 2 show the times (PROVTIME, DTRTIME, and WAITTIME) derived from clinic data were not significantly different (p=.186, p=.098, and p=.837, respectively) from the times generated by the computer model. Since there were no significant differences in times in the clinic and in the model, **H_0 #1** must be accepted and the Status Quo Model is accepted as a valid model.

The remaining ten hypotheses were tested by the one-way Analysis of Variance (ANOVA). Significant differences ($p<.0001$) were found between the models when each dependent variable was tested by the ANOVA (Tables 4-8). Therefore, the Scheffe, a post hoc multiple comparison test, was used to isolate the significant differences (Appendix A, Tables A3-A7). Comparing the means of each of the dependent variables in all of the computer models, the Scheffe reveals significant differences between the means in all but four of the comparisons.

Hypothesis #2. This hypothesis tests the differences between the Status Quo Model and Alternative Model #1.

H_0 #2: There is not a significant difference between the Status Quo Model and Alternative Model #1.

H_1 #2: There is a significant difference between the Status Quo Model and Alternative Model #1.

The Status Quo Model and Alternative Model #1 were found to be significantly different when the means of the dependent variables in these models were compared by the ANOVA ($p<.0001$) and the Scheffe ($p<.0001$). Therefore, reject **H_0 #2** and accept **H_1 #2**.

Hypothesis #3. This hypothesis tests the differences between the Status Quo Model and Alternative Model #2.

H_0 #3: There is not a significant difference between the Status Quo Model and Alternative Model #2.

H_1 #3: There is a significant difference between the Status Quo Model and Alternative Model #2.

The Status Quo Model and Alternative Model #2 were found to be significantly different ($p<.0001$) when the means of the dependent variables in these models were compared by the ANOVA. The Scheffe found significant differences ($p<.0001$) between the means all of the dependent variables in these two models, except for the variable DTRUTIL ($p=.641$). Therefore, reject $\mathbf{H_0}$ **#3** and accept $\mathbf{H_1}$ **#3**.

Hypothesis #4. This hypothesis tests the differences between the Status Quo Model and Alternative Model #3.

$\mathbf{H_0}$ **#4**: There is not a significant difference between the Status Quo Model and Alternative Model #3.

$\mathbf{H_1}$ **#4**: There is a significant difference between the Status Quo Model and Alternative Model #3.

The Status Quo Model and Alternative Model #3 were found to be significantly different ($p<.0001$) when the means of the dependent variables in these models were compared by the ANOVA. The Scheffe found significant differences ($p<.023$) between the means all of the dependent variables in these two models, except for the variable TOTALPT ($p=.138$). Therefore, reject $\mathbf{H_0}$ **#4** and accept $\mathbf{H_1}$ **#4**.

Hypothesis #5. This hypothesis tests the differences between the Status Quo Model and Alternative Model #4.

$\mathbf{H_0}$ **#5**: There is not a significant difference between the Status Quo Model and Alternative Model #4.

$\mathbf{H_1}$ **#5**: There is a significant difference between the Status Quo Model and Alternative Model #4.

The Status Quo Model and Alternative Model #4 were found to be significantly different when the means of the dependent variables in these models were compared by

the ANOVA ($p<.0001$) and the Scheffe ($p<.003$). Therefore, reject $\mathbf{H_0}$ **#5** and accept $\mathbf{H_1}$ **#5**.

<u>Hypothesis #6.</u> This hypothesis tests the differences between Alternative Model #1 and Alternative Model #2.

$\mathbf{H_0}$ **#6**: There is not a significant difference between Alternative Model #1 and Alternative Model #2.

$\mathbf{H_1}$ **#6**: There is a significant difference between Alternative Model #1 and Alternative Model #2.

Alternative Model #1 and Alternative Model #2 were found to be significantly different when the means of the dependent variables in these models were compared by the ANOVA ($p<.0001$) and the Scheffe ($p<.0001$). Therefore, reject $\mathbf{H_0}$ **#6** and accept $\mathbf{H_1}$ **#6**.

<u>Hypothesis #7.</u> This hypothesis tests the differences between Alternative Model #1 and Alternative Model #3.

$\mathbf{H_0}$ **#7**: There is not a significant difference between Alternative Model #1 and Alternative Model #3.

$\mathbf{H_1}$ **#7**: There is a significant difference between Alternative Model #1 and Alternative Model #3.

Alternative Model #1 and Alternative Model #3 were found to be significantly different when the means of the dependent variables in these models were compared by the ANOVA ($p<.0001$) and the Scheffe ($p<.0001$). Therefore, reject $\mathbf{H_0}$ **#7** and accept $\mathbf{H_1}$ #7.

<u>Hypothesis #8.</u> This hypothesis tests the differences between Alternative Model #1 and Alternative Model #4.

H_0 #8: There is not a significant difference between Alternative Model #1 and Alternative Model #4.

H_1 #8: There is a significant difference between Alternative Model #1 and Alternative Model #4.

Alternative Model #1 and Alternative Model #4 were found to be significantly different when the means of the dependent variables in these models were compared by the ANOVA ($p<.0001$) and the Scheffe ($p<.0001$). Therefore, reject **H_0 #8** and accept **H_1 #8**.

<u>Hypothesis #9.</u> This hypothesis tests the differences between Alternative Model #2 and Alternative Model #3.

H_0 #9: There is not a significant difference between Alternative Model #2 and Alternative Model #3.

H_1 #9: There is a significant difference between Alternative Model #2 and Alternative Model #3.

Alternative Model #2 and Alternative Model #3 were found to be significantly different when the means of the dependent variables in these models were compared by the ANOVA ($p<.0001$) and the Scheffe ($p<.0001$). Therefore, reject **H_0 #9** and accept **H_1 #9**.

<u>Hypothesis #10.</u> This hypothesis tests the differences between Alternative Model #2 and Alternative Model #4.

H_0 #10: There is not a significant difference between Alternative Model #2 and Alternative Model #4.

H_1 #10: There is a significant difference between Alternative Model #2 and Alternative Model #4.

Alternative Model #2 and Alternative Model #4 were found to be significantly different when the means of the dependent variables in these models were compared by the ANOVA ($p<.0001$) and the Scheffe ($p<.0001$). Therefore, reject **H_0 #10** and accept **H_1 #10**.

Hypothesis #11. This hypothesis tests the differences between Alternative Model #3 and Alternative Model #4.

H_0 #11: There is not a significant difference between Alternative Model #3 and Alternative Model #4.

H_1 #11: There is a significant difference between Alternative Model #3 and Alternative Model #4.

The Alternative Model #3 and Alternative Model #4 were found to be significantly different ($p<.0001$) when the means of the dependent variables in these models were compared by the ANOVA. The Scheffe found significant differences ($p<.0001$) between the means all of the dependent variables in these two models, except for the variables TIME ($p=.936$) and TOTALPT ($p=.744$). Therefore, reject **H_0 #11** and accept **H_1 #11**.

Decision Matrix

Alternative Model #3 had the highest relative rating in the decision matrix in Table 9, followed closely by Alternative Model #4. Alternative Model #1 had the lowest relative rating in the decision matrix.

Table 9

Decision Matrix

Criteria	Status Quo		Alternative Model #1		Alternative Model #2		Alternative Model #3		Alternative Model #4	
	Rating	Value	Rating	Value	Rating	Value	Rating	Value	Rating	Value
TIME (Weight = .8)	3	2.4	1	.8	2	1.6	4.5	3.6	4.5	3.6
ASSTUTIL (Weight = .8)	2	1.6	4	3.2	5	4	3	2.4	1	.8
PROVUTIL (Weight = 1.2)	3	3.6	1	1.2	2	2.4	4	4.8	5	6
DTRUTIL (Weight = .5)	3.5	1.75	5	2.5	3.5	1.75	2	1	1	.5
TOTALPT (Weight = .5)	3.75	1.88	1	.5	2	1	4	2	4.25	2.13
Total Value		11.23		8.2		10.75		**13.8**		13.03

Note. A higher relative rating is better. The relative ratings were averaged when significant differences did not exist between the models. The value is the product of the relative rating and the weight.

Chapter 4

Discussion

Testing for Significance

The five computer models in this study were found to differ significantly ($p<.0001$) based on the results of an ANOVA performed on each of the dependent variables (see Tables 4 - 8). For each dependent variable, an ANOVA compared the variation of the mean within a single computer model to the variation between all of the computer models. Since the variation between the models was found to be significantly greater than the variation within each model, the results of each ANOVA test were significant. When using a statistical tool, such as the ANOVA, it is important to know how much variance is accounted for by the variables. The R^2, a value generated by SPSS®, shows the amount of variance accounted for by the variables in the models. The larger the R^2, the more variance is accounted for, so we want the R^2 to be as large as possible. As much as 99% of the variance ($R^2=.990$) could be accounted for in the ANOVA comparing the dependent variable, ASSTUTIL, while only about 21% of the variance ($R^2=.214$) could be accounted for in the ANOVA comparing the dependent variable, TIME.

A statistically significant finding in an ANOVA indicates that it appears unlikely that all population means are equal, but it does not pinpoint which means are significantly different from each other (Norusis, 1994). Therefore, when the results of an ANOVA are significant, a multiple comparison post hoc test should be performed to isolate the significant differences. Multiple comparison tests isolate significant differences by

comparing all of the possible pairs of means. In this study, the Scheffe multiple comparison test was used because it is more conservative and robust than some of the other multiple comparison tests (Cooper & Emory, 1995). Although the post hoc multiple comparison test used in this study did not find significant differences between four of the pairs of means, all of the ANOVA tests found significant differences between the models.

Model Performance

The model with the fewest resources performed the poorest in this study (see Table 9). Alternative Model #1 had the least resources with just one dental assistant and one DTR. This model had the least desirable performance in three of the five variables studied. In Alternative Model #1 the fewest total patients were seen and the patients spent the longest time in the clinic. Additionally, Alternative Model #1 had the poorest utilization of the provider. Based on the input provided by the dental commander, utilization of the provider is very important and this variable was weighted the highest in the decision matrix.

On the other hand, models with more resources tended to perform better in this study. For example, models with three DTRs (Alternative Models #3 and #4) performed better than models with just one or two DTRs. Also, models with two dental assistants (Status Quo and Alternative Model #3) performed better than models with just one dental assistant (Alternative Models #1 and #2). However, Alternative Model #3 with two dental assistants performed better than Alternative Model #4 primarily because the utilization of the dental assistants was better in Alternative Model #3.

Alternative Models #3 and #4 performed very similarly and their performance was better than the other models. Provider utilization, which was the most important variable to the dental commander, was better in Alternative Models #3 and #4. Also, more total patients were seen in Alternative Models #3 and #4, and patients spent less time in the clinic in Alternative Models #3 and #4. The multiple comparison test did not find significant differences between the means of two of the dependent variables, TIME and TOTALPT in Alternative Models #3 and #4. Although Alternative Model #4 had significantly better utilization of the provider, Alternative Model #3 utilized the dental assistants and DTRs significantly better.

Ideally, the model with the optimal resources (dental assistants and DTRs) should produce significantly better results in all of the dependent variables. Ideally, patients will spend a minimum amount of time in the clinic; the dental assistant, provider and DTR will be maximally utilized; and the most total patients will be seen. Although Alternative Model #3 did not perform significantly better in all of these areas, its overall performance was better than the performance of Alternative Model #4 and the other models. Therefore, Alternative Model #3 was determined to have the optimal resources, i.e. two dental assistants and three DTRs.

Model Validation

Model validation verifies that the model is an accurate representation of the real system. It is important for the model to be valid so the model can be used as a substitute for the real system for the purpose of addressing different "what if" questions or scenarios (Carson, 1986). In this study, the validity of the computer model to accurately represent the endodontic practice at DC #2 was tested both subjectively and objectively. The Status

Quo Model was validated subjectively by establishing face validity with the endodontist. Using animated simulation facilitated the process of establishing face validity since the endodontist could actually "see" the flow of the animated patients through the simulated clinic and compare it to the flow of patients through the real system.

Objective validation involves performing a statistical comparison of model output data to similar data from the real system. Validating a computer model objectively is more rigorous and is generally preferred (Lowery & Martin, 1992). It was possible to objectively validate the Status Quo Model in this study by comparing data generated by the model (Provider in use Time, DTR in use Time, and Waiting Time) to similar data collected at DC #2. Since significant differences were not found between the model output and the real system using the independent samples t-test, the Status Quo Model can be considered, with a reasonable degree of certainty, to accurately represent the endodontic specialty practice at DC #2.

Distributions

According to McGuire (1997) provider service times are rarely represented by a normal distribution, but are more likely to be represented by Lognormal, Weibull, or Beta distributions. The distributions selected in this study were consistent with McGuire's study. The curve fitting software, Stat::Fit®, indicated that a Weibull distribution best fit the provider service times for both exam/eval patients and treatment patients in this study.

Limitations of the Study

One limitation to the study was that only two entities were used in the model to represent all of the different types of endodontic patients. One entity represented

endodontic patients receiving care associated with relatively short provider service times, such as evaluations (evals) and examinations (exams). A second entity represented endodontic patients receiving care with relatively long provider service times, such as endodontic therapy and endodontic surgery. The data collected at DC #2 did not support the use of additional entities, for example there were not enough data on surgery patients to create a separate surgery patient entity. However, the provider service times for most types of endodontic patients are probably fairly well represented by either the short or long provider services times used in this study.

Another limitation of this study was that only five alternatives were compared to determine the optimal resource support for an endodontic specialty practice. Certainly, many more alternatives could have been examined. However, the five alternatives included in this study represented the most probable combinations of dental assistants and DTRs that would be used in an Army dental clinic.

An additional limitation of this study was that cost was not considered in determining the optimal resource support for an endodontist. The scope of this study was intentionally limited, but as reliable cost data becomes more readily available it should be included to more adequately compare all of the possible alternatives.

Chapter 5

Conclusion and Recommendations

Animated computer simulation can be a useful decision support tool. Computer simulation provided a cost effective means to determine the optimal level of resource support (dental assistants and DTRs) for an endodontic specialty practice. This study utilized computer simulation to compare the effects of different levels of resource support on five variables that could easily be measured in the output data. The model in this study with the best overall performance was considered to have the optimal level of resources.

The results of this animated computer simulation study provide some valuable information about the optimal resources required to support an endodontic specialty practice. The results of this study suggest that an endodontic specialty practice will tend to be more productive in terms of the number of patients seen and patients will tend to spend less total time in the clinic when the provider can utilize more DTRs and/or has more dental assistants. Additionally, the provider will tend to be better utilized when he/she can use more DTRs and/or has more dental assistants. However, the percent utilization of the dental assistants and/or DTRs tends to decline when the resource support of an endodontic specialty practice is increased. Of course, under utilizing dental assistants and DTRs is not desirable. Therefore, a model with optimal resources should maximize desirable outcomes, such as more total patients, and minimize undesirable outcomes like under utilization of dental assistants and DTRs.

The decision matrix used in this study provided a more objective way to compare the five computer models and determine which had the optimal resources. It provided an

objective way to account for the few cases where significant differences did not exist between dependent variables in the models. When significant differences did not exist between the means of the dependent variables in two different models, the decision matrix relative ratings could be averaged so that both models received an equal relative rating. Additionally, input from the dental commander regarding the relative importance of the variables could be considered by weighting the variables the decision matrix.

Alternative Model #3 received the highest relative rating in the decision matrix and is considered to have the optimal resources. Therefore, the results of this study indicate that the optimal resource support for the endodontic specialty practice at Fort Lewis includes two dental assistants and three dental treatment rooms.

I recommend that the endodontist at DC #2 be assigned two dental assistants and be given access to three dental treatment rooms, if these resources are available. Implementing this recommendation will not require major changes from the status quo. Since the endodontist already has two dental assistants, this recommendation only involves assigning an additional DTR to the endodontist. Unfortunately, the supply of DTRs is limited since DC #2 supports a dental residency. Therefore, if a third DTR cannot be assigned exclusively to the endodontist, I recommend the endodontist make arrangements to utilize the adjacent DTRs when they are not being utilized by other providers.

The costs associated with the varying number of dental assistants and DTRs in the five computer models were not considered in this study. Therefore, I recommend that a future study be conducted to evaluate the cost versus the benefits of the different scenarios. I also recommend that other uses of this "endodontic" simulation model be

explored, such as studying the impact of changing the patient flow at DC #2. This model could also be modified to study the optimal resource support for other dental specialty practices.

The emphasis today on lowering costs and increasing access requires all health care organizations to operate efficiently. Maximum efficiency depends on optimizing the use of limited resources. This study used animated computer simulation to examine the optimal use of two important resources in dental clinics, dental assistants and DTRs. While this study focused on the endodontic specialty practice at DC #2, the results may be directly applicable to endodontic practices in other clinics with similar floor plans (adjacent DTRs), patient flow, and staff. Additionally, a "re-usable" computer simulation model was developed that can be adapted to serve as a decision support tool at other Army dental clinics.

Appendix A

Table A1

Approximate costs for selected Full Time Equivalents (FTE)

Provider	Compensation	
Military Dentist	$63,212	Salary*
0-5 (14 yrs)	17,000	Bonuses**
	17,647	Benefits†
	$97,859	Total
Civilian Dentist	$51,828	Salary††
(GS 12, Step 5)	12,957	Bonuses‡
	14,253	Benefits†
	79.038	Total
Contract General Dentist	$102,000	Base Salary‡‡
(Germany)	Unknown	Housing/Tuition‡‡
	$102,000	Total
Contract Orthodontist	$206,000	Base Salary‡‡
(Germany)	Unknown	Housing/Tuition‡‡
	$206,000	Total
Contract Oral & Maxillo-	$167,980	Base Salary‡‡
facial Surgeon	21,120	On Call‡‡
(Fort Hood)	$189,000	Total

Note.

* Based on 1997 Pay Chart. Includes base pay, BAQ, and BAS.

** Based on Dental Pay = $4,000; Dental Additional Specialty Pay (DASP) = $8,000; and Board Certification Pay (BCP) = $5,000.

† Based on 22% of annual pay.

†† Based Salary Table No. 97-SEA, Effective January 1997. Includes locality payment for Seattle-Tacoma-Bremerton, WA.

‡ Based on 25% of annual pay.

‡‡ From the Chief of Resource Management, DENCOM. (1997,October 1).

Appendix A

Table A2

Military and Civilian Personnel Assigned to DC #2

Position	Military	Civilian
Dentists		
Endodontists	1	
General Dentists	5	2
Oral & Maxillofacial Surgeons	1	
Periodontists	1	
Prosthodontist	1	
Residents	10	
Total Dentists	19	2
Dental Hygienist	3	1
Dental Therapy Assistants	0	2
Dental Assistants	5	15
Laboratory Technicians	1	3
NCOIC	1	0
Supply Clerk	1	0
Secretary	0	1
Medical Clerks	0	3
Office Automation Clerk	0	1
Total Providers	22	5
Total Support Staff	8	23
Total Clinic Staff	30	28

Note. From the U.S. Army Dental Activity, Fort Lewis, Washington. (1997, October 1). The residents rotate through other clinics, so all ten are not at DC #2 at the same time.

Appendix A

Table A3

Scheffe's Multiple Comparison of Dependent Variable: TIME

Model	Versus Model	Mean Difference		Standard Error	Significance
Status Quo	Alt. 1	-28.35	*	2.443	.000
	Alt. 2	-10.47	*	2.443	.001
	Alt. 3	8.24	*	2.443	.023
	Alt. 4	10.46	*	2.443	.001
Alt. 1	Status Quo	28.35	*	2.443	.000
	Alt. 2	17.88	*	2.443	.000
	Alt. 3	36.60	*	2.443	.000
	Alt. 4	38.81	*	2.443	.000
Alt. 2	Status Quo	10.47	*	2.443	.001
	Alt. 1	-17.88	*	2.443	.000
	Alt. 3	18.71	*	2.443	.000
	Alt. 4	20.93	*	2.443	.000
Alt. 3	Status Quo	-8.24	*	2.443	.023
	Alt. 1	-36.60	*	2.443	.000
	Alt. 2	-18.71	*	2.443	.000
	Alt. 4	2.21		2.443	.936
Alt. 4	Status Quo	-10.46	*	2.443	.001
	Alt. 1	-38.81	*	2.443	.000
	Alt. 2	-20.93	*	2.443	.000
	Alt. 3	-2.21		2.443	.936

Note. * indicates the mean difference is significant at the .05 level.

Appendix A

Table A4

Scheffe's Multiple Comparison of Dependent Variable: ASSTUTIL

Model	Versus Model	Mean Difference		Standard Error	Significance
Status Quo	Alt. 1	-39.20	*	.197	.000
	Alt. 2	-40.15	*	.197	.000
	Alt. 3	-2.35	*	.197	.000
	Alt. 4	15.64	*	.197	.000
Alt. 1	Status Quo	39.20	*	.197	.000
	Alt. 2	-.95	*	.197	.000
	Alt. 3	36.85	*	.197	.000
	Alt. 4	54.84	*	.197	.000
Alt. 2	Status Quo	40.15	*	.197	.000
	Alt. 1	.95	*	.197	.000
	Alt. 3	37.80	*	.197	.000
	Alt. 4	55.79	*	.197	.000
Alt. 3	Status Quo	2.35	*	.197	.000
	Alt. 1	-36.85	*	.197	.000
	Alt. 2	-37.80	*	.197	.000
	Alt. 4	17.99	*	.197	.000
Alt. 4	Status Quo	-15.64	*	.197	.000
	Alt. 1	-54.84	*	.197	.000
	Alt. 2	-55.79	*	.197	.000
	Alt. 3	-17.99	*	.197	.000

Note. * indicates the mean difference is significant at the .05 level.

Appendix A

Table A5

Scheffe's Multiple Comparison of Dependent Variable: PROVUTIL

Model	Versus Model	Mean Difference		Standard Error	Significance
Status Quo	Alt. 1	11.20	*	.327	.000
	Alt. 2	8.40	*	.327	.000
	Alt. 3	-4.02	*	.327	.000
	Alt. 4	-5.97	*	.327	.000
Alt. 1	Status Quo	-11.20	*	.327	.000
	Alt. 2	-2.80	*	.327	.000
	Alt. 3	-15.21	*	.327	.000
	Alt. 4	-17.17	*	.327	.000
Alt. 2	Status Quo	-8.40	*	.327	.000
	Alt. 1	2.80	*	.327	.000
	Alt. 3	-12.42	*	.327	.000
	Alt. 4	-14.37	*	.327	.000
Alt. 3	Status Quo	4.02	*	.327	.000
	Alt. 1	15.22	*	.327	.000
	Alt. 2	12.42	*	.327	.000
	Alt. 4	-1.95	*	.327	.000
Alt. 4	Status Quo	5.97	*	.327	.000
	Alt. 1	17.17	*	.327	.000
	Alt. 2	14.37	*	.327	.000
	Alt. 3	1.95	*	.327	.000

Note. * indicates the mean difference is significant at the .05 level.

Appendix A

Table A6

Scheffe's Multiple Comparison of Dependent Variable: DTRUTIL

Model	Versus Model	Mean Difference		Standard Error	Significance
Status Quo	Alt. 1	-9.55	*	.557	.000
	Alt. 2	.88		.557	.641
	Alt. 3	5.50	*	.557	.000
	Alt. 4	12.25	*	.557	.000
Alt. 1	Status Quo	9.55	*	.557	.000
	Alt. 2	10.43	*	.557	.000
	Alt. 3	15.04	*	.557	.000
	Alt. 4	21.80	*	.557	.000
Alt. 2	Status Quo	-.88		.557	.641
	Alt. 1	-10.43	*	.557	.000
	Alt. 3	4.61	*	.557	.000
	Alt. 4	11.37	*	.557	.000
Alt. 3	Status Quo	-5.50	*	.557	.000
	Alt. 1	-15.04	*	.557	.000
	Alt. 2	-4.61	*	.557	.000
	Alt. 4	6.75	*	.557	.000
Alt. 4	Status Quo	-12.25	*	.557	.000
	Alt. 1	-21.80	*	.557	.000
	Alt. 2	-11.37	*	.557	.000
	Alt. 3	-6.75	*	.557	.000

Note. * indicates the mean difference is significant at the .05 level.

Appendix A

Table A7

Scheffe's Multiple Comparison of Dependent Variable: TOTALPT

Model	Versus Model	Mean Difference		Standard Error	Significance
Status Quo	Alt. 1	1.66	*	.103	.000
	Alt. 2	1.19	*	.103	.000
	Alt. 3	-.27		.103	.138
	Alt. 4	-.42	*	.103	.003
Alt. 1	Status Quo	-1.66	*	.103	.000
	Alt. 2	-.48	*	.103	.000
	Alt. 3	-1.94	*	.103	.000
	Alt. 4	-2.08	*	.103	.000
Alt. 2	Status Quo	-1.19	*	.103	.000
	Alt. 1	.48	*	.103	.000
	Alt. 3	-1.46	*	.103	.000
	Alt. 4	-1.60	*	.103	.000
Alt. 3	Status Quo	.27		.103	.138
	Alt. 1	1.94	*	.103	.000
	Alt. 2	1.46	*	.103	.000
	Alt. 4	-.14		.103	.744
Alt. 4	Status Quo	.42	*	.103	.003
	Alt. 1	2.08	*	.103	.000
	Alt. 2	1.60	*	.103	.000
	Alt. 3	.14		.103	.744

Note. * indicates the mean difference is significant at the .05 level.

Appendix B

Department Of Defense Standardized Dental Classification System

The oral health status of personnel shall be classified as follows:

1. Class 1. Patients not requiring dental treatment or reevaluation within 12 months.

Criteria:

a. No dental caries or defective restorations.

b. Arrested caries for which treatment is not indicated.

c. Healthy periodontium, no bleeding on probing; oral prophylaxis not indicated.

d. Replacement of missing teeth not indicated.

e. Unerupted, partially erupted, or malposed teeth that are without historical, clinical, or radiographic signs or symptoms of pathosis and are not recommended for prophylactic removal.

2. Class 2. Patients who have oral conditions that, if not treated or followed up, have the potential but are not expected to result in dental emergencies within 12 months.

Criteria:

a. Treatment or follow up indicated for dental caries with minimal extension into dentin or minor defective restorations easily maintained by the patient where the condition does not cause definitive symptoms.

b. Interim restorations or prostheses that can be maintained by the patient for a 12-month period. This includes teeth that have been restored with permanent restorative materials but for which protective coverage is indicated.

c. Edentulous areas requiring prostheses but not on an immediate basis.

d. Periodontal disease or periodontium exhibiting:

1. Requirement for oral prophylaxis.

2. Requirement for maintenance therapy; this includes stable or non-progressive mucogingival conditions requiring periodic evaluation.

3. Non-specific gingivitis.

4. Early or mild adult periodontitis.

e. Unerupted, partially erupted, or malposed teeth that are without historical, clinical, or radiographic signs or symptoms of pathosis, but which are recommended for prophylactic removal.

f. Active orthodontic treatment.

g. Temporomandibular disorder patients in maintenance therapy.

3. Class 3. Patients who have oral conditions that if not treated are expected to result in dental emergencies within 12 months. Patients should be placed in Class 3 when there are questions in determining classification between Class 2 and Class 3.

Criteria:

a. Dental caries, tooth fractures, or defective restorations where the condition extends beyond the dentinoenamel junction and causes definitive symptoms; dental caries with moderate or advanced extension into dentin; and defective restorations not maintained by the patient.

b. Interim restorations or prostheses that cannot be maintained for a 12-month period. This includes teeth that have been restored with permanent restorative materials but for which protective coverage is indicated.

c. Periodontal diseases or periodontium exhibiting:

1. Acute gingivitis or pericoronitis.
2. Active moderate to advanced periodontitis.
3. Periodontal abscess.
4. Progressive mucogingival condition.
5. Periodontal manifestations of systemic disease or hormonal disturbances.

d. Edentulous areas or teeth requiring immediate prosthodontic treatment for adequate mastication, communication, or acceptable esthetics.

e. Unerupted, partially erupted, or malposed teeth with historical, clinical, or radiographic signs or symptoms of pathosis that are recommended for removal.

f. Chronic oral infections or other pathologic lesions including:

1. Pulpal or periapical pathology requiring treatment.
2. Lesions requiring biopsy or awaiting biopsy report.

g. Emergency situations requiring therapy to relieve pain, treat trauma, treat acute oral infections, or provide timely follow-up care (e.g., drain or suture removal) until resolved.

h. Temporomandibular disorders requiring active treatment.

4. Class 4. Patients who require dental examinations. This includes patients who require annual or other required dental examinations and patients whose dental classifications are unknown.

Appendix C

Health Affairs Memorandum (HA POLICY 96-024)

[Categorical Listing] [Numerical Listing]

THE ASSISTANT SECRETARY OF DEFENSE

WASHINGTON, DC 20301-1200

HEALTH AFFAIRS

JAN 29 1996

MEMORANDUM FOR TRICARE LEAD AGENTS
THROUGH: SURGEON GENERAL OF THE ARMY
SURGEON GENERAL OF THE NAVY
SURGEON GENERAL OF THE AIR FORCE

SUBJECT: Inclusion of Dentistry in TRICARE Regions

I have recently met with the Tri-Service Dental Chiefs and expressed my desire that dentistry be included as an integral component of the regional TRICARE system. Our Military Health Services System (MHSS) must not exclude important and critical components of an integrated health care delivery system for our beneficiaries.

In that vein, I request that the Lead Agents immediately initiate movement toward substantial and meaningful inclusion of the dental resources in your respective regions in order that we can truly have an integrated health care delivery system worldwide. Please formally report your progress to me by the summer TRICARE conference in July 1996.

The Service Dental Chiefs have developed a dental readiness metric that will allow the Services and the Department to assess the readiness of our active duty forces accurately. On a quarterly basis, the Dental Chiefs will report to the Assistant Secretary of Defense (Health Affairs) through their Surgeons General the Dental Readiness of all our active duty forces. Our goal is to achieve 95 percent of all active duty forces in dental classification 1 or 2. To meet this formidable goal, we need to incorporate the dental health care delivery system into the regional TRICARE system as soon as possible.

I look forward to your reports of progress in truly integrating our MHSS!

Stephen C. Joseph, M.D., M.P.H.

HA POLICY 96-024

cc:
Service Dental Chiefs

[Top]

Appendix D

Hypotheses

Model Validation

Hypothesis #1.

H_0 #1: There is not a significant difference between the output data of the Status Quo Model and the empirical clinical data.

H_1 #1: There is a significant difference between the output data of the Status Quo Model and the empirical clinical data.

Model Comparison

Hypothesis #2.

H_0 #2: There is not a significant difference between the Status Quo Model and Alternative Model #1.

H_1 #2: There is a significant difference between the Status Quo Model and Alternative Model #1.

Hypothesis #3.

H_0 #3: There is not a significant difference between the Status Quo Model and Alternative Model #2.

H_1 #3: There is a significant difference between the Status Quo Model and Alternative Model #2.

Hypothesis #4.

H_0 #4: There is not a significant difference between the Status Quo Model and Alternative Model #3.

H_1 #4: There is a significant difference between the Status Quo Model and Alternative Model #3.

Hypothesis #5.

H_0 #5: There is not a significant difference between the Status Quo Model and Alternative Model #4.

H_1 #5: There is a significant difference between the Status Quo Model and Alternative Model #4.

Hypothesis #6.

H_0 #6: There is not a significant difference between Alternative Model #1 and Alternative Model #2.

H_1 #6: There is a significant difference between Alternative Model #1 and Alternative Model #2.

Hypothesis #7.

H_0 #7: There is not a significant difference between Alternative Model #1 and Alternative Model #3.

H_1 #7: There is a significant difference between Alternative Model #1 and Alternative Model #3.

Hypothesis #8.

H_0 #8: There is not a significant difference between Alternative Model #1 and Alternative Model #4.

H_1 #8: There is a significant difference between Alternative Model #1 and Alternative Model #4.

Hypothesis #9.

H_0 #9: There is not a significant difference between Alternative Model #2 and Alternative Model #3.

H_1 #9: There is a significant difference between Alternative Model #2 and Alternative Model #3.

Hypothesis #10.

H_0 #10: There is not a significant difference between Alternative Model #2 and Alternative Model #4.

H_1 #10: There is a significant difference between Alternative Model #2 and Alternative Model #4.

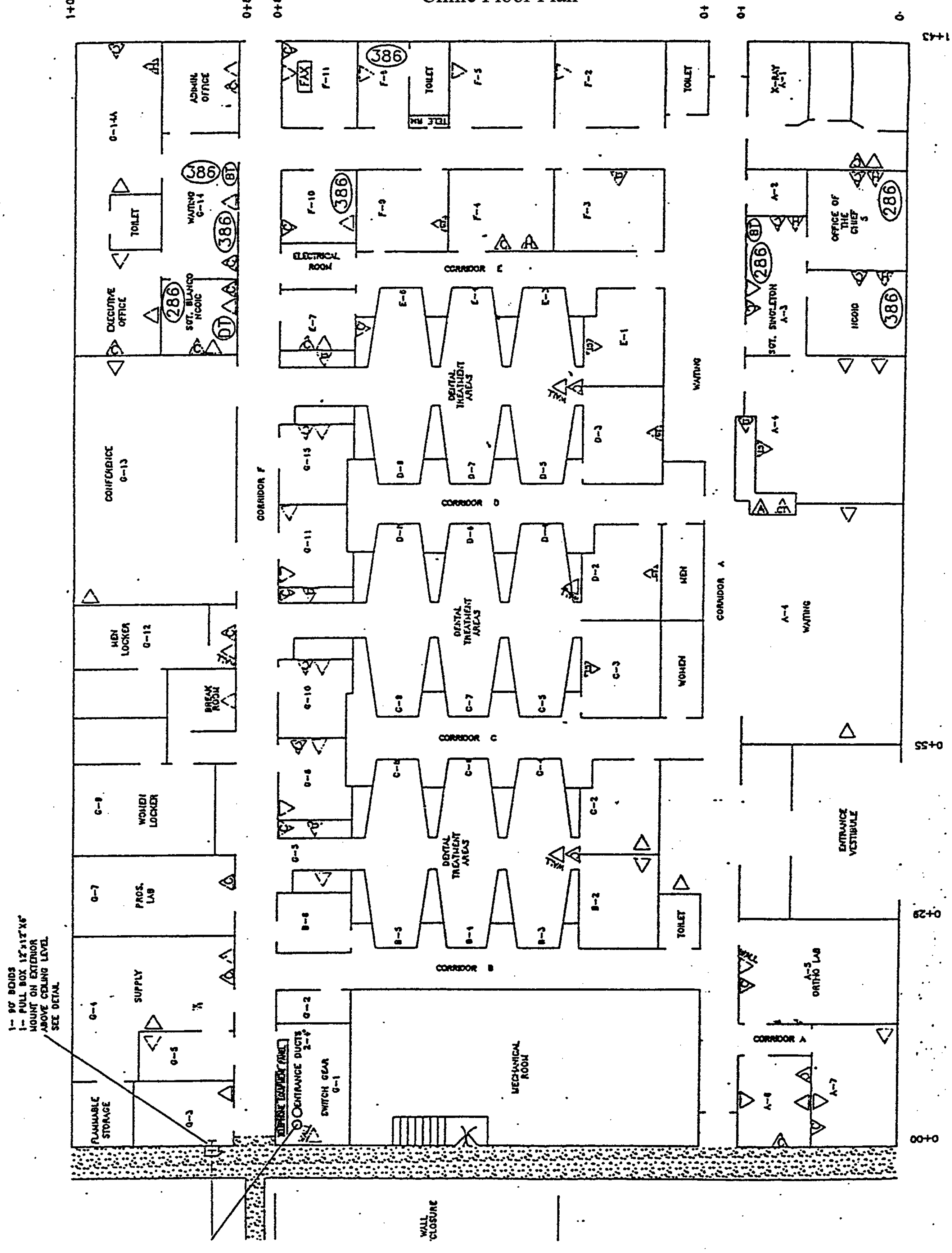
Hypothesis #11.

H_0 #11: There is not a significant difference between Alternative Model #3 and Alternative Model #4.

H_1 #11: There is a significant difference between Alternative Model #3 and Alternative Model #4.

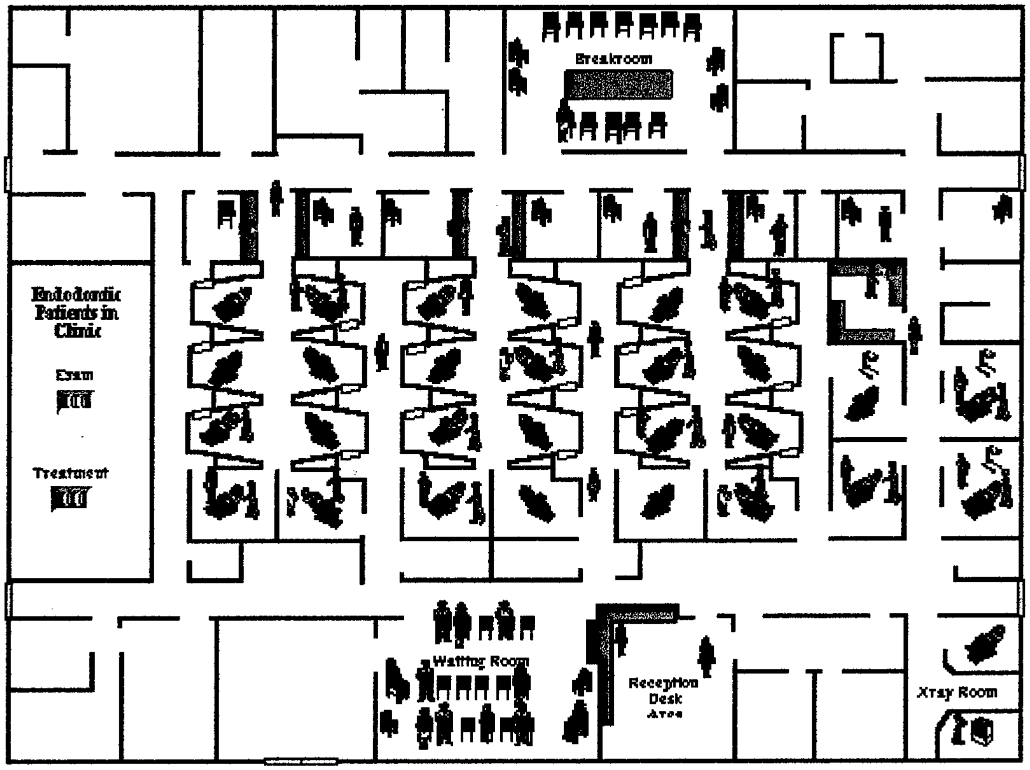
Appendix E

Clinic Floor Plan



Appendix F

Animated Simulation of the Dental Clinic



Appendix G

Data Collection Form G1

Simulation Model Data Collection Form
Treatment, X-Ray, and Operatory Set-up/Clean-up Times
(Endodontics)
Date: ________________

Patient Type Eval/Exam - E Post Op - POT Routine Treatment - Tx Surgery - Sx		**Treatment Time** (time doctor is with patient) Start Time	Finish Time	Leave Blank	**X-Ray Time** (if applicable) Time Sent To X-ray	Time Returned From X-ray	Leave Blank	**Set-up + Clean-up Time** (in minutes)
1								
2								
3								
4								
5								
6								
7								
8								
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Appendix G

Data Collection Form G2 (Clinic Sign-in Sheet)

(Check One)
☐ Appointment Roster
☐ Sick Call Roster

DENTAL CLINIC VISITS

DENTAL CLINIC ____

DATE

PAGE ____ of ____

INFORMATION REQUIRED BY THE PRIVACY ACT OF 1974

AUTHORITY: 5 U.S.C., section 301; 10 U.S C., sections 1071-1085; 50 U.S.C., Supplement IV, Appendix 454, as amended. PRINCIPAL PURPOSE: Verify enrollment in the Defense Eligibility Enrollment Reporting System and/or participation in the Delta Dental Insurance Program. ROUTINE USES: To determine eligibility for dental care. DISCLOSURE: Voluntary. Witholding information may severely limit the extent of treatment this facility may provide.

NAME	RANK OR FM	SOCIAL SECURITY NUMBER	UNIT	TIME		BRANCH OF SERVICE			
				IN	OUT	ARMY	NAVY/CG/MARINE	AIR FORCE	OTHER

MAMC Form 416-D
1 Jul 89

Supersedes edition dated 1 Aug 85, which may be used.

Appendix H

Status Quo Model Program Listing

```
************************************************************************
*                      Formatted Listing of Model:                     *
*                 C:\MedMod3\models\Gmp\gmp1ksq.MOD                    *
************************************************************************
```

Time Units: Minutes
Distance Units: Feet

```
************************************************************************
*                              Locations                               *
************************************************************************
```

Name	Cap	Units	Stats	Rules
ChairEndo2	1	1	Time Series	Oldest
ChairEndo3	1	1	None	Oldest
ChairEndo1	1	1	Time Series	Oldest
ChairEndo4	1	1	None	Oldest
Reception	1	1	None	Oldest
Entrance	Inf	1	None	Oldest
Exit_	inf	1	None	Oldest
Waiting_Room	100	1	Time Series	Oldest
ChairGD	5	1	None	Oldest
ChairSC	3	1	None	Oldest
Xray2	1	1	None	Oldest
ChairPerio	1	1	None	Oldest
ChairHyg	4	1	None	Oldest
ChairExam	1	1	None	Oldest
ChairOther	9	1	None	Oldest
Xray	1	1	None	Oldest
Autoclave	50	1	None	Oldest
Reception_Q	Inf	1	None	Oldest
Reception2	1	1	None	Oldest
Tray_Q	Inf	1	None	Oldest
Xray_Q	Inf	1	None	Oldest

****
* Clock downtimes for Locations *
****

Loc	Frequency	First Time	Priority	Scheduled	Disable	Logic
Entrance	1	480	99	Yes	No	wait 180

****
* Entities *
****

Name	Speed (fpm)	Stats
Pt_Endo_Ex	114	Time Series
Pt_Endo_Tx	114	Time Series
Pt_Perio_Ex	114	None
Pt_Perio_Tx	114	None
Pt_Perio_Sx	114	None
Pt_Perio_Pot	114	None
Pt_Exam	114	None
Pt_Other	114	None
Pt_GD	114	None
Pt_GD_Sc	114	None
Pt_Hyg	114	None
Used_Tray	0	None
tray_group	0	None
Used_TrayE	0	None

****
* Resources *
****

Name	Units	Stats	Res Search	Ent Search	Path	Motion
Endodontist	1	By Unit	Closest	Oldest	Clinic_net Home: nOffice2 (Return)	Empty: 114 fpm Full: 114 fpm
Gen_Dent	5	None	Closest	Oldest	Clinic_net Home: nOffice1 (Return)	Empty: 114 fpm Full: 114 fpm

Periodontist	1	None	Closest	Oldest	Clinic_net Home: nOffice4 (Return)	Empty: 114 fpm Full: 114 fpm
Other_Dent	5	None	Closest	Oldest	Clinic_net Home: nOffice5 (Return)	Empty: 114 fpm Full: 114 fpm
Exam_Dent	1	None	Closest	Oldest	Clinic_net Home: nOffice4 (Return)	Empty: 114 fpm Full: 114 fpm
Endo_Asst	2	By Unit	Closest	Oldest	Clinic_net Home: nSteril2 (Return)	Empty: 114 fpm Full: 114 fpm
Hygienist	1	None	Closest	Oldest	Clinic_net Home: nSteril3 (Return)	Empty: 114 fpm Full: 114 fpm
Dent_Asst	20	None	Closest	Oldest	Clinic_net Home: nSteril3 (Return)	Empty: 114 fpm Full: 114 fpm
Receptionist	2	None	Closest	Oldest	Recep_net Home: nRecep2 (Return)	Empty: 114 fpm Full: 114 fpm

****
*   Clock downtimes for Resources   *
****

Res	Freq.	First Time	Priority	Scheduled	Node	Disable	Log
Endodontist	10 hr	5 hr	99	Yes	nBreak	No	wait 30
Gen_Dent	10hr	5hr	99	Yes	nBreak	No	wait 30
Periodontist	10 hr	5 hr	99	Yes	nBreak	No	wait 30
Other_Dent	10 hr	5 hr	99	Yes	nBreak	No	wait 30
Exam_Dent	10 hr	5 hr	99	Yes	nBreak	No	wait 30
Endo_Asst	4 hr	4 hr	100	Yes	nBreak	No	wait 30
Dent_Asst	4hr	4hr	100	Yes	nBreak	No	wait 30
Receptionist	4hr	4hr	100	Yes	N3	No	wait 30

```
**********************************************************************
*                      Resource Node Logic                           *
**********************************************************************
```

Res	Node	Entry Logic	Exit Logic
Endo_Asst	N29	graphic 2	graphic 1

```
**********************************************************************
*                          Processing                                *
**********************************************************************
```

PROCESS

Entity	Location	Operation
Pt_Endo_Ex	Entrance	INC vPt_Endo_Ex

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Endo_Ex	Reception_Q	FIRST 1	MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Pt_Endo_Ex	Reception_Q	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Endo_Ex	Reception	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Endo_Ex	Reception	USE Receptionist, 999 FOR N(2,1)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Endo_Ex	Waiting_Room	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Endo_Ex	Waiting_Room	graphic 2 Attr1=clock()

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Endo_Ex	ChairEndo2	FIRST 1	graphic 1

				GET Endo_Asst, 700 MOVE WITH Endo_Asst LOG "Ex Pt waiting", attr1
	Pt_Endo_Ex	ChairEndo1	ALT	graphic 1 GET Endo_Asst, 700 MOVE WITH Endo_Asst LOG "Ex Pt waiting", attr1

PROCESS

Entity	Location	Operation
Pt_Endo_Ex	ChairEndo2	graphic 4 WAIT N(2, 1) FREE Endo_Asst JOINTLY GET Endodontist AND Endo_Asst, 999 attr3=clock() WAIT 7+W(1.68, 11.3) CREATE 1 AS Used_TrayE

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Endo_Ex	Exit_	FIRST 1	Graphic 1 FREE Endo_Asst FREE Endodontist MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Used_TrayE	ChairEndo2	Get endo_asst, 600 Wait N(5, 1)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Used_TrayE	Tray_Q	FIRST 1	MOVE WITH Endo_Asst

PROCESS

Entity	Location	Operation
Pt_Endo_Ex	ChairEndo1	graphic 4 WAIT N(2, 1) FREE Endo_Asst JOINTLY GET Endodontist AND Endo_Asst, 999 attr3=clock() WAIT 7+W(1.68, 11.3) CREATE 1 AS Used_TrayE

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Endo_Ex	Exit_	FIRST 1	Graphic 1 FREE Endo_Asst FREE Endodontist MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Used_TrayE	ChairEndo1	Get endo_asst, 600 wait N(5, 1)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Used_TrayE	Tray_Q	FIRST 1	MOVE WITH Endo_Asst

PROCESS

Entity	Location	Operation
Used_TrayE	Tray_Q	FREE Endo_Asst GROUP 3

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	tray_group	Autoclave	FIRST 1	MOVE WITH Endo_Asst

PROCESS

Entity	Location	Operation
tray_group	Autoclave	FREE Endo_Asst

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	tray_group	EXIT	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Endo_Ex	Exit_	DEC vPt_Endo_Ex

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Endo_Ex	EXIT	FIRST 1	LOG "Ex provider time",

attr3

PROCESS

Entity	Location	Operation
Pt_Endo_Tx	Entrance	INC vPt_Endo_Tx

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Endo_Tx	Reception_Q	FIRST 1	MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Pt_Endo_Tx	Reception_Q	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Endo_Tx	Reception	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Endo_Tx	Reception	USE Receptionist, 999 FOR N(2,1)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Endo_Tx	Waiting_Room	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Endo_Tx	Waiting_Room	Graphic 2 Attr2=clock()

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Endo_Tx	ChairEndo1	FIRST 1	graphic 1 GET Endo_Asst, 200 MOVE WITH Endo_Asst LOG "Tx Pt wait time", attr2
	Pt_Endo_Tx	ChairEndo2	ALT	graphic 1 GET Endo_Asst, 200 MOVE WITH Endo_Asst LOG "Tx Pt wait time", attr2

PROCESS

Entity	Location	Operation
Pt_Endo_Tx	ChairEndo1	graphic 4 WAIT N(2, 1) FREE Endo_Asst JOINTLY GET Endodontist AND Endo_Asst, 250 Attr4=clock() WAIT 30+W(2.32, 50.7) CREATE 1 AS Used_Tray

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Endo_Tx	Exit_	FIRST 1	Graphic 1 FREE Endo_Asst

FREE Endodontist
MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Used_Tray	ChairEndo1	GET Endo_Asst WAIT 7+P5(9.66, 61.7)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Used_Tray	Tray_Q	FIRST 1	MOVE WITH Endo_Asst

PROCESS

Entity	Location	Operation
Used_Tray	Tray_Q	FREE Endo_Asst GROUP 3

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	tray_group	Autoclave	FIRST 1	MOVE WITH Endo_Asst

PROCESS

Entity	Location	Operation
tray_group	Autoclave	FREE Endo_Asst

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	tray_group	EXIT	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Endo_Tx	ChairEndo2	graphic 4 WAIT N(2, 1) FREE Endo_Asst JOINTLY GET Endodontist AND Endo_Asst, 250 Attr4=clock() WAIT 30+W(2.32, 50.7) CREATE 1 AS Used_Tray

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Endo_Tx	Exit_	FIRST 1	Graphic 1 FREE Endo_Asst FREE Endodontist MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Used_Tray	ChairEndo2	GET Endo_Asst

WAIT 7+P5(9.66, 61.7)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Used_Tray	Tray_Q	FIRST 1	MOVE WITH Endo_Asst

PROCESS

Entity	Location	Operation
Pt_Endo_Tx	Exit_	DEC vPt_Endo_Tx

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Endo_Tx	EXIT	FIRST 1	LOG "Tx provider time",

attr4

PROCESS

Entity	Location	Operation
Pt_Exam	Entrance	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Exam	Reception_Q	FIRST 1	MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Pt_Exam	Reception_Q	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Exam	Reception	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Exam	Reception	USE Receptionist, 999 FOR N(2,1)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Exam	Waiting_Room	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Exam	Waiting_Room	graphic 2

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Exam	ChairExam	FIRST 1	graphic 1 GET Dent_Asst

MOVE WITH Dent_Asst

PROCESS

Entity	Location	Operation
Pt_Exam	ChairExam	graphic 3 wait 1 FREE Dent_Asst JOINTLY GET Exam_Dent AND Dent_Asst, 999 Wait 1+3.16*(1./((1./U(0.5,0.5))-1.))**(1./2.91) Create 1 as Used_Tray

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Exam	Xray_Q	FIRST 1	graphic 1 Free exam_dent MOVE WITH Dent_Asst

PROCESS

Entity	Location	Operation
Pt_Exam	Xray_Q	Wait 1 FREE Dent_Asst

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Exam	Xray	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Exam	Xray	graphic 2 Wait N(6, 1)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Exam	Exit_	FIRST 1	graphic 1 MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Pt_Exam	Exit_	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Exam	EXIT	FIRST 1	

PROCESS

Entity	Location	Operation
Used_Tray	ChairExam	GET Dent_Asst Wait B(2.93, 4.96e+03, 1, 7.59e+03)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Used_Tray	EXIT	FIRST 1	FREE Dent_Asst

PROCESS

Entity	Location	Operation
Pt_Perio_Ex	Entrance	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Ex	Reception_Q	FIRST 1	MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Pt_Perio_Ex	Reception_Q	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Ex	Reception	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Perio_Ex	Reception	USE Receptionist, 999 for N(2,1)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Ex	Waiting_Room	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Perio_Ex	Waiting_Room	graphic 2

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Ex	ChairPerio	FIRST 1	graphic 1 GET Dent_Asst MOVE WITH Dent_Asst

PROCESS

Entity	Location	Operation
Pt_Perio_Ex	ChairPerio	graphic 3 wait N(2,1) FREE Dent_Asst JOINTLY GET Periodontist and Dent_Asst Wait 5+W(1.96, 20.4) CREATE 1 AS Used_TrayE

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Ex	Exit_	FIRST 1	graphic 1 FREE Periodontist FREE Dent_Asst MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Pt_Perio_Ex	Exit_	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Ex	EXIT	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Perio_Pot	Entrance	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Pot	Reception_Q	FIRST 1	MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Pt_Perio_Pot	Reception_Q	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Pot	Reception	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Perio_Pot	Reception	USE Receptionist, 999 FOR N(2, 1)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Pot	Waiting_Room	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Perio_Pot	Waiting_Room	graphic 2

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Pot	ChairPerio	FIRST 1	graphic 1 GET Dent_Asst MOVE WITH Dent_Asst

PROCESS

Entity	Location	Operation
Pt_Perio_Pot	ChairPerio	graphic 3 wait N(2,1) FREE Dent_Asst JOINTLY GET Periodontist and Dent_Asst Wait 5+W(2.1, 4.97) CREATE 1 AS Used_TrayE

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Pot	Exit_	FIRST 1	graphic 1 FREE Periodontist FREE Dent_Asst MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Pt_Perio_Pot	Exit_	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Pot	EXIT	FIRST 1	

PROCESS

Entity	Location	Operation
Used_TrayE	ChairPerio	GET Dent_Asst Wait N(4,1)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Used_TrayE	EXIT	FIRST 1	Free Dent_Asst

PROCESS

Entity	Location	Operation
Pt_Perio_Tx	Entrance	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Tx	Reception_Q	FIRST 1	MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Pt_Perio_Tx	Reception_Q	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Tx	Reception	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Perio_Tx	Reception	USE Receptionist, 999 For N(2,1)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Tx	Waiting_Room	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Perio_Tx	Waiting_Room	graphic 2

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Tx	ChairPerio	FIRST 1	graphic 1 GET Dent_Asst MOVE WITH Dent_Asst

PROCESS

Entity	Location	Operation
Pt_Perio_Tx	ChairPerio	graphic 3 wait N(2, 1) FREE Dent_Asst JOINTLY GET Periodontist and Dent_Asst Wait 12+L(29.5, 29.2) CREATE 1 AS Used_Tray

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Tx	Exit_	FIRST 1	graphic 1 FREE Periodontist FREE Dent_Asst MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Pt_Perio_Tx	Exit_	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Tx	EXIT	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Perio_Sx	Entrance	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Sx	Reception_Q	FIRST 1	MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Pt_Perio_Sx	Reception_Q	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Sx	Reception	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Perio_Sx	Reception	USE Receptionist, 999 For N(2,1)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Sx	Waiting_Room	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Perio_Sx	Waiting_Room	graphic 2

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Sx	ChairPerio	FIRST 1	graphic 1 GET Dent_Asst MOVE WITH Dent_Asst

PROCESS

Entity	Location	Operation
Pt_Perio_Sx	ChairPerio	graphic 3 wait N(2, 1) FREE Dent_Asst JOINTLY GET Periodontist and Dent_Asst Wait 25+W(2.68, 102) CREATE 1 AS Used_Tray

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Sx	Exit_	FIRST 1	graphic 1 FREE Periodontist FREE Dent_Asst MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Pt_Perio_Sx	Exit_	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Perio_Sx	EXIT	FIRST 1	

PROCESS

Entity	Location	Operation
Used_Tray	ChairPerio	GET Dent_Asst Wait N(15, 5)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Used_Tray	EXIT	FIRST 1	FREE Dent_Asst

PROCESS

Entity	Location	Operation
Pt_GD	Entrance	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_GD	Reception_Q	FIRST 1	MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Pt_GD	Reception_Q	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_GD	Reception	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_GD	Reception	USE Receptionist, 999 For N(2,1)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_GD	Waiting_Room	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_GD	Waiting_Room	graphic 2

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_GD	ChairGD	FIRST 1	graphic 1 GET Dent_Asst MOVE WITH Dent_Asst

PROCESS

Entity	Location	Operation
Pt_GD	ChairGD	graphic 3 wait N(2, 1) FREE Dent_Asst JOINTLY GET Gen_Dent and Dent_Asst Wait 10+32.5*(1./((1./U(0.5,0.5))-1.))**(1./3.65) CREATE 1 AS Used_Tray

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_GD	Exit_	FIRST 1	graphic 1 FREE Gen_Dent FREE Dent_Asst MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Pt_GD	Exit_	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_GD	EXIT	FIRST 1	

PROCESS

Entity	Location	Operation
Used_Tray	ChairGD	GET Dent_Asst Wait N(15, 5)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Used_Tray	EXIT	FIRST 1	Free Dent_Asst

PROCESS

Entity	Location	Operation
Pt_GD_Sc	Entrance	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_GD_Sc	Reception_Q	FIRST 1	MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Pt_GD_Sc	Reception_Q	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_GD_Sc	Reception	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_GD_Sc	Reception	Use Receptionist, 999 For N(2,1)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_GD_Sc	Waiting_Room	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_GD_Sc	Waiting_Room	graphic 2

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_GD_Sc	ChairSC	FIRST 1	graphic 1 GET Dent_Asst MOVE WITH Dent_Asst

PROCESS

Entity	Location	Operation
Pt_GD_Sc	ChairSC	graphic 3 wait N(2, 1) FREE Dent_Asst JOINTLY GET Gen_Dent and Dent_Asst Wait 10+32.5*(1./((1./U(0.5,0.5))-1.))**(1./3.65) CREATE 1 AS Used_Tray

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_GD_Sc	Exit_	FIRST 1	graphic 1 FREE Gen_Dent FREE Dent_Asst MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Pt_GD_Sc	Exit_	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_GD_Sc	EXIT	FIRST 1	

PROCESS

Entity	Location	Operation
Used_Tray	ChairSC	GET Dent_Asst Wait N(15, 5)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Used_Tray	EXIT	FIRST 1	Free Dent_Asst

PROCESS

Entity	Location	Operation
Pt_Other	Entrance	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Other	Reception_Q	FIRST 1	MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Pt_Other	Reception_Q	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Other	Reception	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Other	Reception	Use Receptionist, 999 for N(2,1)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Other	Waiting_Room	FIRST 1	

PROCESS

Entity	Location	Operation
Pt_Other	Waiting_Room graphic 2	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Other	ChairOther	FIRST 1	graphic 1 GET Dent_Asst MOVE WITH Dent_Asst

PROCESS

Entity	Location	Operation
Pt_Other	ChairOther	graphic 3 wait N(2, 1) FREE Dent_Asst JOINTLY GET Other_Dent and Dent_Asst Wait N(15,8) CREATE 1 AS Used_Tray

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Other	Exit_	FIRST 1	graphic 1 FREE Other_Dent FREE Dent_Asst MOVE ON Clinic_net

PROCESS

Entity	Location	Operation
Pt_Other	Exit_	

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Pt_Other	EXIT	FIRST 1	

PROCESS

Entity	Location	Operation
Used_Tray	ChairOther	GET Dent_Asst Wait N(15, 5)

ROUTING

Blk	Output	Destination	Rule	Move Logic
1	Used_Tray	EXIT	FIRST 1	Free Dent_Asst

****
* Arrivals *
****

Entity	Location	Qty each	First Time	Occurrences	Frequency
Pt_Endo_Ex	Entrance	1	0+N(0,3)	1	1
Pt_Endo_Tx	Entrance	2	15+N(0,3)	1	1
Pt_Endo_Ex	Entrance	1	65+N(0,3)	1	1
Pt_Endo_Ex	Entrance	1	75+N(0,3)	1	1
Pt_Endo_Tx	Entrance	1	180+N(0,3)	1	1
Pt_Endo_Ex	Entrance	1	310+N(0,3)	1	1
Pt_Endo_Ex	Entrance	2	326+N(0,3)	1	1
Pt_Endo_Tx	Entrance	1	335+N(0,3)	1	1
Pt_Endo_Ex	Entrance	1	415+N(0,3)	1	1
Pt_Endo_Ex	Entrance	1	430+N(0,3)	1	1
Pt_Endo_Tx	Entrance	1	440+N(0,3)	1	1
Pt_Exam	Entrance	1	5+N(0,3)	1	1
Pt_Exam	Entrance	1	35+N(0,3)	1	1
Pt_Exam	Entrance	2	65+N(0,3)	1	1
Pt_Exam	Entrance	4	95+N(0,3)	1	1
Pt_Exam	Entrance	6	120+N(0,3)	1	1
Pt_Exam	Entrance	6	150+N(0,3)	1	1
Pt_Exam	Entrance	4	180+N(0,3)	1	1
Pt_Exam	Entrance	6	210+N(0,3)	1	1
Pt_Exam	Entrance	2	300+N(0,3)	1	1
Pt_Exam	Entrance	1	420+N(0,3)	1	1
Pt_Perio_Sx	Entrance	1	0+N(0,3)	1	1

Pt_Perio_Ex	Entrance	1	152+N(0,3)	1	1
Pt_Perio_Tx	Entrance	1	182+N(0,3)	1	1
Pt_Perio_Ex	Entrance	1	220+N(0,3)	1	1
Pt_Perio_Ex	Entrance	1	240+N(0,3)	1	1
Pt_Perio_Pot	Entrance	1	269+N(0,3)	1	1
Pt_Perio_Sx	Entrance	1	330+N(0,3)	1	1
Pt_GD	Entrance	3	0+N(0,3)	1	1
Pt_GD	Entrance	3	30+N(0,3)	1	1
Pt_GD	Entrance	2	60+N(0,3)	1	1
Pt_GD	Entrance	2	90+N(0,3)	1	1
Pt_GD	Entrance	2	120+N(0,3)	1	1
Pt_GD	Entrance	4	180+N(0,3)	1	1
Pt_GD	Entrance	4	240+N(0,3)	1	1
Pt_GD	Entrance	4	330+N(0,3)	1	1
Pt_GD	Entrance	4	390+N(0,3)	1	1
Pt_GD_Sc	Entrance	4	0+N(0,3)	1	1
Pt_GD_Sc	Entrance	2	60+N(0,3)	1	1
Pt_GD_Sc	Entrance	2	120+N(0,3)	1	1
Pt_Other	Entrance	3	0+N(0,3)	1	1
Pt_Other	Entrance	2	30+N(0,3)	1	1
Pt_Other	Entrance	2	90+N(0,3)	1	1
Pt_Other	Entrance	3	150+N(0,3)	1	1
Pt_Other	Entrance	3	210+N(0,3)	1	1
Pt_Other	Entrance	3	270+N(0,3)	1	1
Pt_Other	Entrance	3	315+N(0,3)	1	1
Pt_Other	Entrance	3	330+N(0,3)	1	1
Pt_Other	Entrance	3	360+N(0,3)	1	1
Pt_Other	Entrance	3	390+N(0,3)	1	1
Pt_Other	Entrance	1	450+N(0,3)	1	1

```
***************************************************************************
*                              Attributes                                 *
***************************************************************************
```

<u>ID</u> <u>Type</u> <u>Classification</u>

#Pt_Endo_Ex wait time
attr1 Integer Entity

#Pt_Endo_Tx wait time
attr2 Integer Entity

#Pt_Endo_Ex provider contact time
attr3 Integer Entity

#Pt_Endo_Tx provider contact time
attr4 Integer Entity

****
* Variables (global) *
****

ID	Type	Initial value	Stats
vPt_Endo_Ex	Integer	0	Time Series
vPt_Endo_Tx	Integer	0	Time Series

Note. The program listings for the alternative models differ from the Status Quo Model program in the number of dental assistants (resources) and/or dental treatment rooms (locations).

Appendix I

Preference Chart

	TIME	TOTALPT	PROVUTIL	ASSTUTIL	DTRUTIL	Value	Weight
TIME		>	<	=	=	8	0.8
TOTALPT	<		<<	<	>	5	0.5
PROVUTIL	>	>>		>	>>	12	1.2
ASSTUTIL	=	>	<		=	8	0.8
DTRUTIL	=	<	<<	=		5	0.5

Symbol	Meaning	Points
>>	much more	4
>	more	3
=	equal	2
<	less	1
<<	much less	0

Note. From Systematic Systems Approach by Thomas H. Athey (1982).

Appendix J

Acronyms

ADA	American Dental Association
ADCS	U.S. Army Dental Care System
ANOVA	Analysis of Variance
ASD(HA)	Assistant Secretary of Defense (Health Affairs)
CEO	Chief Executive Officer
CONUS	Continental United States
DENCOM	U.S. Army Dental Command
DC#2	Dental Clinic #2
DCRI	Dental Care Reengineering Initiative
DoD	Department of Defense
DTA	Dental Therapy Assistant
DTR	Dental Treatment Rooms
FTE	Full Time Equivalent
FY	Fiscal Year
HCO	Health Care Organization
MHSS	Military Health Services System
OCONUS	Out of the Continental United States
OSD(HA)	Office of the Assistant Secretary of Defense (Health Affairs)
RDH	Registered Dental Hygienist

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